PETROLEUM REFINER

SPECIALIZED FOR THE OIL REFINING INDUSTRY, INCLUDING PETRO-CHEMICAL ENGINEERING, PETROLEUM SYNTHETICS AND NATURAL GASOLINE

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GRADY TRIPLETT
Editor

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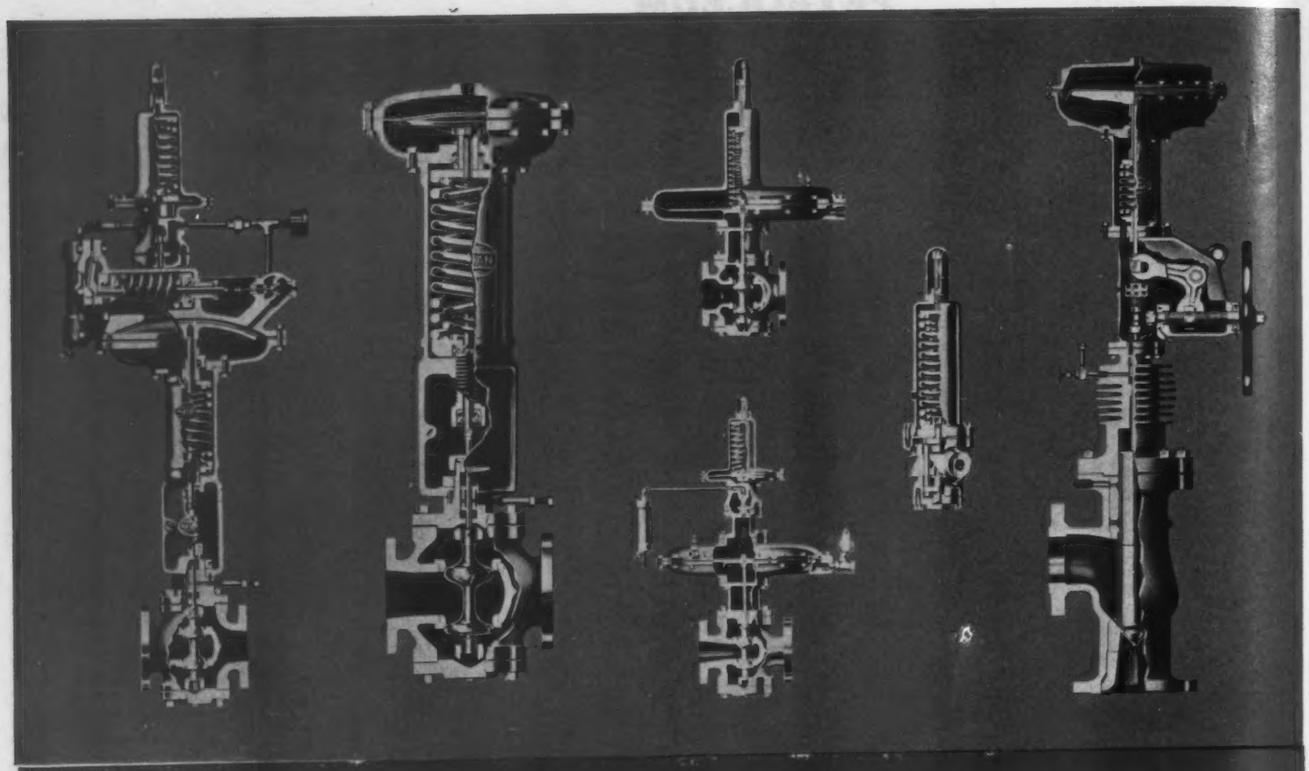

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THE LOOK BOX

FROM the report of the Baruch Committee the work sheet for the synthetic-rubber program can be drawn. For the whole program its direction is to give one authority full control; to the petroleum industry the direction is to stick with processes already selected; to the full plant building program the advice is to so synchronize its several phases that sufficient rubber for military necessity be produced in 1943.

Work Sheet

Aptly and concisely it singled out hampering influences responsible for earlier delay. Confusion because of three agencies of government failing to work in harmony, controversy within the petroleum industry as to proper processes, and conflict as to source material were scored for the evident purpose of assuring their removal. Its high praise of the men of technical training can in large measure be taken by men within the petroleum industry.

Already the program has been given a single authority in William M. Jeffers, who has instituted some recommendations and is shaping the future course in keeping with directions laid down in the report, which is printed in full in this issue of PETROLEUM REFINER.

After examining all projects the committee came to the conclusion that proposals are adequate for building in 1943 sufficient plant capacity for the final production of 705,000 tons of Buna S rubber per year, 132,000 tons of Butyl rubber, 40,000 tons of neoprene. Along with plant construction the report made this pertinent observation:

"If the construction program can be met on dates specified there will be produced during 1943, 400,000 tons of Buna S. . . ."

In this the committee came to conclusion identical with testimony before investigating committees and numerous private expression to the effect that 1943 is a critical year. Unless Buna S rubber is made in that quantity military activity of armed forces will be hampered, there will be damaging restrictions on public transportation and such curtailment of civilian rubber requirements as to drag against production of war products.

While Buna S rubber is not the whole of requirements it dominates all considerations and the task for 1943 can be measured with what petroleum, rubber and chemical industries can accomplish in its 365 days. It is not permissable to ask if it can be done because the necessity is such that it must be done.

As analyzed by the committee, butadiene for 463,000 tons of the Buna S total will come from petroleum and 242,000 tons of butadiene from alcohol. It is this schedule and the processes already selected that the committee recommends holding rigidly.

IN August the plant-building schedule of the whole synthetic-rubber program was made public and completion of all plants during the coming year was accepted as possible. Capacity for 235,000 tons of butadiene was listed for 1942 completion and 525,000 tons in 1943. Their total is sufficient for 705,000 tons of Buna S rubber by addition of styrene and other chemicals in polymerization.

In The Mill

Within the industry the complaint has been that priority ratings were the only handicap against com-

In Appreciation . . .

AN ISSUE of the magnitude of this War Products Issue of *Petroleum Refiner* is made possible only through the application of much cooperation. The publishers consequently wish to thank the various organizations and individuals who have taken the time from a very busy life to make the editorial contributions published herewith.

We believe that when you shall have finished reading this issue and file it away for reference, you will have reached the conclusion that these technologists and staff writers who have contributed the editorial material have done an exceedingly worthwhile thing. We, and the readers of *Petroleum Refiner* are deeply indebted to them.

At the same time we wish to express our appreciation to the manufacturers and service companies throughout the United States whose cooperation in the advertising pages supplement the editorial content. Readers will find that the advertising pages present almost an encyclopedia of information on the products and services so necessary to the oil industry's program of producing critical war products. Not long ago a reader made the comment that he found the advertising pages of *Petroleum Refiner* fully as interesting as are the editorial pages. This should be true in all instances, because, while men in the refining business work through processes, information on the equipment and services used in the operation of those processes is vitally essential. It is our belief that those concerns who advertise regularly in *Petroleum Refiner* as well as those who may appear only in this issue, have made a genuine contribution, through their advertising space, to that store of information which means intelligent operation of any plant.

pletion in 1943. On this the committee made the pointed observation that the rubber administrator must assure materials. If materials are assured, the petroleum industry will be at fault unless it meets the requirements of the critical year, 1943.

Measured by capacity, plant requirements are not excessive. If as much as 50,000 barrels of butane could be concentrated daily in one spot, petroleum refining alone could provide sufficient butadiene for both military and civilian rubber needs. Statistics of the United States Bureau of Mines give the industry three times that amount of butane. It is not concentrated and it has other uses, consequently butadiene plants must be several and scattered. In relation to all of petroleum this full complement of synthetic rubber would require less than one percent of the total.

Not Too Big a Job

THERE is encouragement in reducing the requirement to barrels, since the industry in normal years expands its refining capacity far more than 50,000 barrels. For this year it must adapt expansion of new processes where they fit existing raw-material sources. It is a task small in barrels, difficult in adaptation and of necessity that can accept but one answer.

Fortunately the recommendations of the committee are flavored with vision. It gave recognition to the fact that the economy of this country is interwoven with automotive transportation; that tires for automobiles cannot be separated for working and living even in the stress of war.

In part this recognition is responsible for the recommendation that the prospect for Buna S rubber be expanded by 140,000 tons, with 100,000 tons of butadiene from petroleum, the remainder from alcohol. Here it expressed faith in the ingenuity of refining technology, for it asked that the amount from oil be provided by conversion of existing equipment to butadiene manufacture.

A New Order

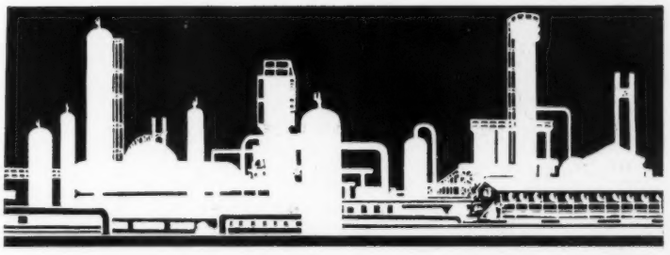
IT IS pardonable that the petroleum industry flavors its critical year of 1943 with vision. This minimum of 400,000 tons of Buna S rubber before the calendar runs out need not forbid looking ahead even beyond the duration. There are indications that three industries, oil, rubber and chemistry, are building another permanent industry. Its success will mean that loss of the rubber plantations of the Far East was temporary for the United States, permanent to the Far East.

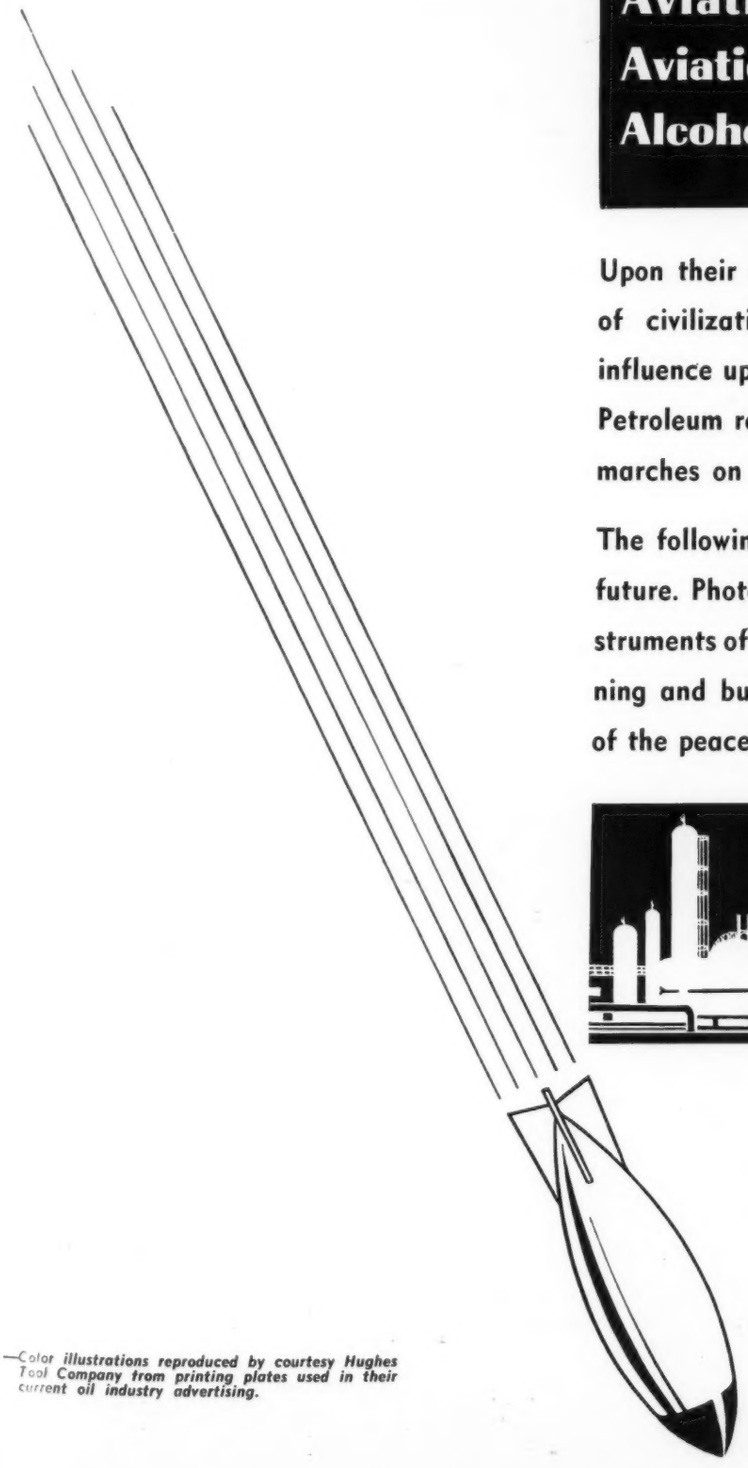
PETROLEUM'S WAR PRODUCTS

Synthetic Rubber
Aviation Gasoline
Aviation Lubricants . Toluol
Alcohol . Plastics, Etc.

Upon their supply and performance rests the fate of civilization. Equally important will be their influence upon human affairs in the peace to come. Petroleum refining rises to meet this challenge and marches on to victory.

The following pages illustrate the present and the future. Photographs show the rubber consuming instruments of war for which the industry's hectic planning and building are being made. The story tells of the peacetime future of these wartime products.





—Color illustrations reproduced by courtesy Hughes Tool Company from printing plates used in their current oil industry advertising.

Bullet proof tanks of this Douglas B-19 alone require as much rubber as 125 to 150 automobile tires — and the tank protection is but a part of the rubber involved.

UNDER the lash of war, petroleum refining is driving through an expansion which in two years will equal what otherwise might have involved half a century. As part of an industrial revolution without parallel it must advance its own products to the status of military requirements. Beyond that it is taking on the role of assistance wherein other industries are not capable of meeting military requirements, as in explosives; while it moves into the strange terrain of supplanting a lost natural resource, such as rubber.

For the moment the task, brought to reality by war, must be measured by war. The one purpose is military success. Destruction is the objective of production. Laboratory, pilot plant and processing equipment have their vision fixed on winning a war. Until that is written into the record attention cannot be turned to the only fruit that ever grows in the footprints of Mars. If science did not translate its tools of destruction into tools of construction, civilization long ago would have had final sacrifice on its pagan altars.

Always mankind reaps something beneficial from the crisis, which compels shortening the time cycle of scientific advancement. To realize that the normal course without disaster and death would be

preferable, is not to deny that the sword may be reshaped into the plowshare and that a better plowshare is through the sword more quickly made.

In this refining is unique. It faces no period of retooling its plants once the conflict ends. What it makes now is as promising for peace as it is significant for war. On this score it need not disturb its immediate concentration by doubt of future. Given a peace whose economics are favorable, petroleum will provide its share of a new world of technology.

Developments in petroleum refining were part of the estimate given by Dr. Charles M. A. Stine, vice president of E. I. du Pont de Nemours & Company, before the meeting of the American Chemical Society two months ago:

"Already our world of 1940, in which we took pardonable if mistaken pride, is so distant in the past that it has become an antiquity, as seen through scientific eyes. The inconceivables of two years ago are today's realities.

"More than a century was consumed in bringing the crude rubber production of the world up to a million tons annually. The United States alone is now undertaking to accomplish almost as mighty a feat in less than two years by the manufacture of chemical rubbers from petroleum, alcohol, and coal and limestone."

Synthetic rubber has but recently come through the political crucible. A confused public still waits for it in doubt and hope. Plants now building will not be in full production for another year. That men in petroleum circles still wonder if this rubberlike material, part of it from oil, is permanent or temporary is understandable. To the technologist, however, synthetic rubber is an assured product, superior to the latex from the tree *Hevea brasilinesis,* whose native home was the Amazon valley although it covered 8,000,000 acres of the equatorial Far East when war came in the Pacific Ocean. This conviction is based on what science has accomplished when

Enough Rubber to make 26,000 golf balls is required in this motorized anti-aircraft gun carriage. Photo by Burt Moritz.

More than 75,000 tons of rubber in every new battleship.

given the task of providing other products superior to natural raw materials, nylon being an example.

Aviation gasoline, prime essential of conflict in the clouds, already is classed as the ordinary motor fuel of the future. While its output increases with military necessity, laboratory and pilot plant are sending even better fuels to the testing grounds. Gasoline of 150-octane rating is as frequently mentioned today as was the 100-octane product 10 years ago.

Toluol is a precious liquid today because upon nitration it becomes the arch destroyer, tri-nitrotoluol, of the demolition bomb. Tomorrow it will be turned into dye chemistry and as a solvent will permit protective coating to be placed upon what men build to replace what they now destroy.

Alcohols, now restricted to the war program, later will enlarge the field of plastics a hundredfold. Ammonia, also an explosive ingredient, has the low-yielding acres of the earth awaiting its place in fertilizer.

These are petroleum products being made or to be made in order that a war will be won. More significant is what the chemist knows and has no time to produce. Oil is a universe of hydrocarbons. It is a part of the bomb that wipes out a block in a single explosion. It may be part of the anesthetic which holds the wounded pilot at rest while the surgeon saves a life.

Accomplishments and prospects of hydrocarbon chemistry are of such magnitude that the men of the industry are prone to over-emphasis. The estimate of Dr. Stine places oil in proper relationship. It is part but not the whole of a technical renaissance. Measured by what science can and will accomplish, the part is small; measured by its own previous accomplishments, the part is great. Summing up what petroleum technology has undertaken will clarify what may be done. Petroleum refining alone is not charged with providing a million tons of synthetic rubber each year. It is building plants to assure three fourths of the butadiene and part of the styrene that make the Buna rubbers. These in turn must be taken by the rubber industry for working into something akin to crude rubber and finally shaping into usable articles. Only Butyl rubber will be wholly of petroleum-hydrocarbon content and this in turn will pass to rubber plants for manufacture. It is well for the petroleum industry to realize that tire moulding is no part of the plants now building.

Trimmed to its realities, however, the contribution of refining is outstanding. No other industry has advanced so far and so rapidly from its peacetime activity into wartime necessity. Before it could match plant capacity with military estimates for aviation gasoline and lubricants, it had to supplement the supply of toluol to the extent that coke-oven capacity could not match explosive requirements.

Then the fall of Singapore changed the rubber situation from an academic discussion into an industrial reality. It has grown to a task of more than a million tons and oil has assumed three fourths of the total. But steel, the essential of new plants, was itself a scarce product. The industry learned so rapidly about butadiene production that confusion came along with assurance. Meanwhile the routine of providing gasoline and fuels for industrial and civilian needs came upon disruption of normal transportation.

The stress imposed is such that scant attention has been given the other technological advancements, which are part and by-product of the transformation in refining.

WHAT these things mean when peace comes will depend on what kind of world peace brings. In transportation it will be a different world, wherein distance is measured in hours rather than miles. Aviation engineers are talking of engines of 100,000 horsepower; freight planes with crews of 30 men; flying ranges of 5000 miles. The figures were mentioned by William B. Stout before the 1942 annual meeting of the Natural Gasoline Association of America, whose estimate of the airplane when peace comes was then summed up as follows:

"This thing has come to a point where aviation is becoming a fundamental of our living. With these freight ships flying the world, with our engines, the

This scout car requires more rubber than a seven passenger limousine — and the number building staggers the imagination. Photo by Burt Moritz.

In addition to rubber for tires, tubes, insulation, padding, etc., each fighting aircraft needs more gasoline and lubricants each hour than the average motorist uses in a month. Official Navy Photo.

only freight ships that can fly those routes to date, they are going to be the background of the greatest era of prosperity that this world has ever seen. Winning this war is going to be a job that will seem hard and long but the very fact that we have to develop ten big freighters or more for every military ship, that we have to carry tons in these ships instead of pounds in the ships we have been building, that we have to navigate distances in what we now call impossible weather without any difficulty, and we are able to do it now; with all these things that leaves us after the war with a background for the greatest commercial development the world has ever seen. We can bring the world together in a way that no other force has ever done. Mechanically we are again going to do a human thing that will bring the world to one line of thought and into understanding instead of misunderstanding. If it is possible for us to just police the world for a while to keep each nation from cutting the other's throat we may bring an era of something new in the matter of civilization."

There is difference of opinion as to when the sky rather than the oceans will take over transportation between continents. In aviation circles there is no difference of conviction that this will come. It is

seriously proposed for World War II. Enough is being done now to convince even the layman that air transport is coming. It is only when engineers give assurance that freight hauling by air will come to be cheaper than by tramp steamer that the layman questions the program.

Too many men of knowledge and reliability, however, give assurance that the airplane is the transportation medium of the future for those outside aviation circles to class it as unreasonable.

The same men hold striking convictions as to air transportation over land areas. The small airplane for individual use is not a machine to be built. It is here and awaits the time when it can be put into civilian hands. Again the testimony comes from Engineer Stout, who told his Tulsa audience:

"Then we come to the private-owner-plane proposition and I'll predict that 75 percent of the people in this room will be flying their own airplanes before very long when the war is over. It won't be the kind of planes you are thinking about, but, let me tell you a story. A few weeks ago I went out to a certain field by invitation and a plane flew in over the field, stopped about as high as this ceiling above where a crowd of us were standing, opened the door, dropped out a rope ladder, a passenger climbed down, the pilot reeled up the ladder, backed off, turned around and flew away. It's not hearsay. I saw it . . ."

It adds up to something fantastic: cargo airplanes so large and fast they will carry freight between continents cheaper than water transportation; huge land airplanes, pulling gliders, which will cut loose at destinations while the air train speeds on its way; airplanes so small and so different that the individual will fly safely between home and city or between cities.

In such a world of mechanics, aviation-grade gasoline and aviation-grade lubricants become the standard product rather than the exceptional product.

Even here the laboratory already has surpassed the acme of a few months—100-octane aviation gasoline. Motor fuels of 150-octane rating are a laboratory possibility. Other qualities are as advanced as the anti-knock qualification. The research chemist is as confident of their ultimate production and use as the aeronautical engineer is of his big motors and little motors. The two complement each other, for the accomplishment consists of providing more horsepower with less weight. A smaller motor can do that when it is charged with a fuel of higher compression ratio.

Furthermore there will be oil involved in building the globe-girdling airplane world. Just as petroleum is an ingredient of the Plexiglas nose of the bomber, there will be oil in the windows of peacetime machines. Instead of metal, required for armament in the warplane, those for peace will require plastic bodies and the field of plastics is a field of hydrocarbons, wherein the toluol and alcohols will be shifted to the making of materials not now known.

WHILE the aeronautical engineer builds and contemplates, the automotive engineer sketches. His production line has been taken over but his imagination is active. Instead of accepting the airways as deserted highways he is prepared to build in keeping with advancement. The next automobile will be like the present automobile only in that it is propelled by an internal-combustion engine and runs on wheels!

The composite of what can be done means that the future automobile will weigh no more than half the old requirement. A body of plastic will have its color impregnated in the material. With a motor that can deliver one horsepower of energy for each pound of weight, the engine will be placed over the rear axle and parallel to it. Its doors and windows will be sliding panels instead of hinged attachments. Along with a sealed cooling system for the supercharged motor there will be an air-conditioning unit for the passengers. For the lighter models a gallon of fuel will give 50 miles of distance.

There are calculations to indicate that the cost, like the weight, will be reduced by half.

Already the last passenger car off the production line a few months back has aged 20 years and the design engineer has not ceased his sketch making.

For this design the refining industry is ready. The lowest octane rating predicted for the automobile of the future is 80, while many predict that 100-octane aviation gasoline will move into the house brand niche. Lubricants that came promptly into production once aviation specifications were written likewise will serve the smaller motor of higher compression ratio.

But the hydrocarbon has a place in building the next automobile. In Plexiglas, which has a hydrocarbon ingredient, the airplane has found a vision-giving plastic superior to glass and one that will be incorporated in the future automobile. Its seats of sponge rubber rather than springs will be covered with a product superior to fabric and the two will be adaptations from rubber of petroleum source. Its tires may be part of the same barrel of oil that contributes a few miles of its travel. Hard plastics of instrument boards and paneling will be fashioned by use of alcohols, now possible from refining. Engine mountings and radiator hose are other chances for oil to build the machine that it must propel and lubricate.

In providing the fuel and lubricants for transportation, whether by air or land, refining will accept what is provided. That will be merely improvement. Beyond these lies the future of refining when peace comes. It is petro-chemistry and consists of recovering hydrocarbons previously ignored, or by synthesis building hydrocarbons previously beyond the realm of refining. Along with accepting the innovations of mechanics and science, it will contribute part of the technology that is compressing fifty years of normal progress into two years of stress.

The question, "is synthetic rubber here to stay?" is answered on the following pages. Men responsible for processes in refining have no doubt of its permanency. Men who know the cost of natural rubber are as confident. Those who have worked out processes by which natural rubber has come to be all or part of 32,000 useful items, look upon a synthetic product as more desirable.

With synthetic rubber the procedure of the chemist will be reversed. He took natural latex and by adding chemicals converted it into a useful material. Now he must by chemistry build useful qualities into the raw material, changing it for different uses. Consequently the prospect is for a hundred or a thousand types of synthetic raw material. Thus far only the problem has been recognized. It is as extensive as the ingenuity of research.

Synthetic rubber is here to stay not because of what it is but because of what can be done with it.

When the last bomb is dropped there will be no dismantling of toluol units. This aromatic hydrocarbon can be converted into a score of solvents, adapted to high-grade motor fuel or used in the dye industry.

Because the expansion of ammonia production for explosives went into plants outside the refining industry, little attention has been given the fact that natural gas is one part of its source. It was petroleum technology which had the methane-steam process ready for the war program.

Of the many future uses of ammonia, fertilizers come first. From the petroleum hydrocarbon its output may be expanded with the needs of the soil. Given sufficient of it and farm output doubles. Thus a step in high-pressure synthesis may come to the refining plant, where the product that provides man more food will in turn provide the refrigeration to preserve the food.

Although not in commercial stage, glycerine can be had by synthesis of petroleum gases. So far there has been no shortage of this product from the soap factories. Should that come about, refining will be in position to provide the propellant for explosives as well as their demolition charge, for nitric acid can be had by oxidation of ammonia and nitroglycerine.

While automotive engineers carry forward their competition between air-cooled and liquid-cooled motors, little noticed has been the fluid that keeps this engine functioning. It is a petroleum synthetic —ethylene glycol, plus air and water. That future automobile includes a closed cooling system and the petroleum-refining plant will provide its coolant along with its fuel and lubricant.

Glycol is within the alcohol group, where petroleum synthesis is moving into competition with other chemical processing.

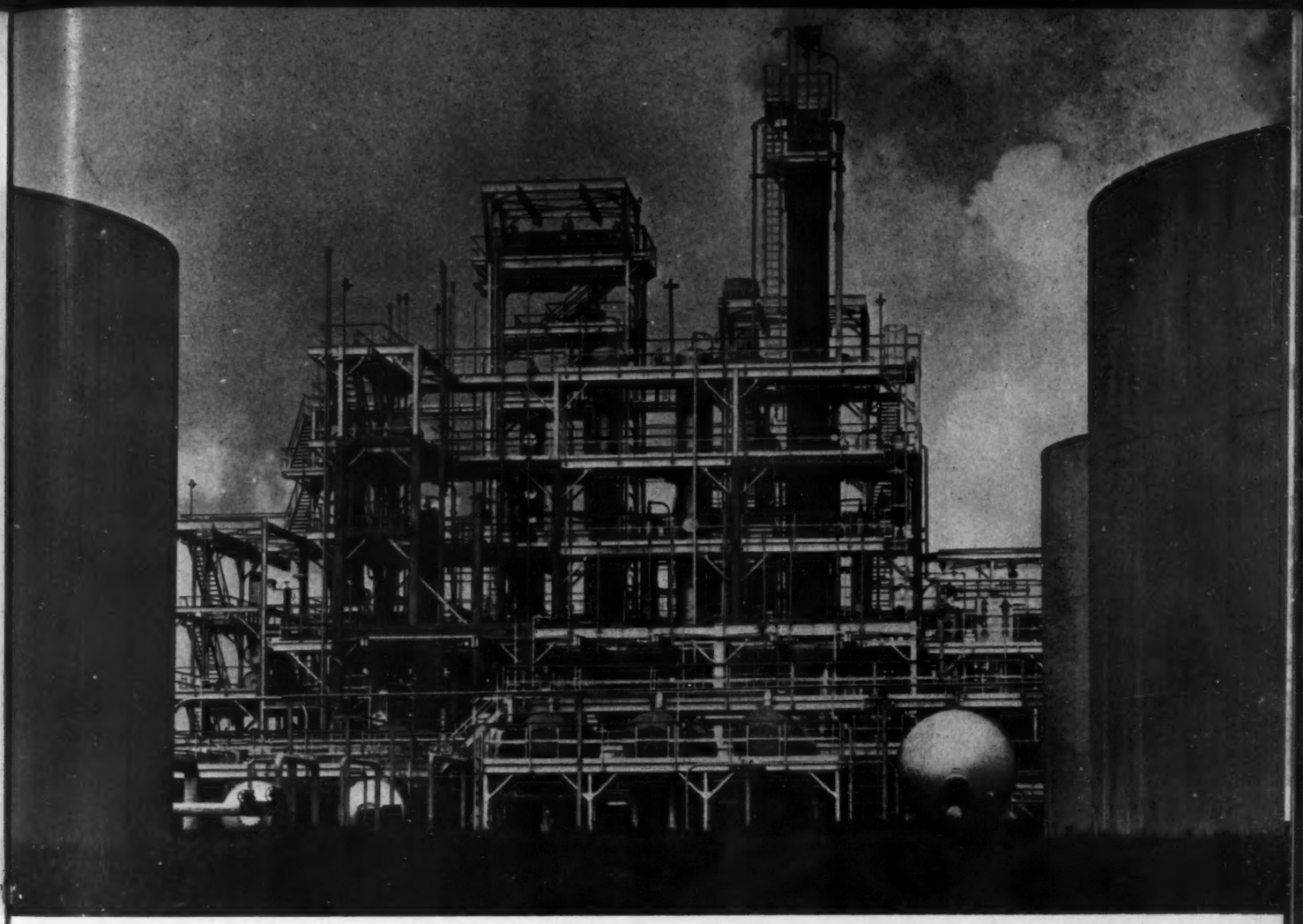
Methyl alcohol, first made by the distillation of wood, has been a synthetic product in recent years. Now it can be had by catalytic synthesis of petroleum by-product gases. In turn it is the raw material source for formaldehyde, which goes into synthetic plastics and resins. Formaldehyde, however, may come directly from petroleum gases, which means that the resins for the growing plastic industry have a source in petroleum. Phenol is the other ingredient and this can be made synthetically from benzene, which will be produced along with butadiene in high-temperature cracking.

Ethyl and isopropyl alcohols are other useful chemicals within reach of petro-chemistry.

These are but a few of the chemicals possible from petroleum. In his speech before the American Chemical Society, Dr. Stine gave petroleum this possibility in chemistry:

"A barrel of crude oil contains literally thousands of chemical compounds. The chemist has long been fascinated by the possibility that almost anything under the sun might be created with these chemical building blocks of hydrogen and carbon; that simply by the addition of oxygen and other elements in the proper combination, he might obtain new alcohols, esters, acids, solvents, perfumes, pharmaceuticals and organic synthetics of every type. Catalytic-cracking processes and adaptations of them brought very recently to high stages of performances, are now leading toward this goal and taking petroleum chemistry into a realm once exclusive to coal-tar industry."

Processes by which these things are possible are silenced by necessity of war. For the present complete information must not be given. Perhaps the major contribution is the adaptation of solvents to the recovery of pure hydrocarbon compounds, after they have been made. Where the desired component cannot be separated by fractionation, a solvent attaches to one hydrocarbon and releases others. In turn the solvent is separated from the compound, which is left pure.

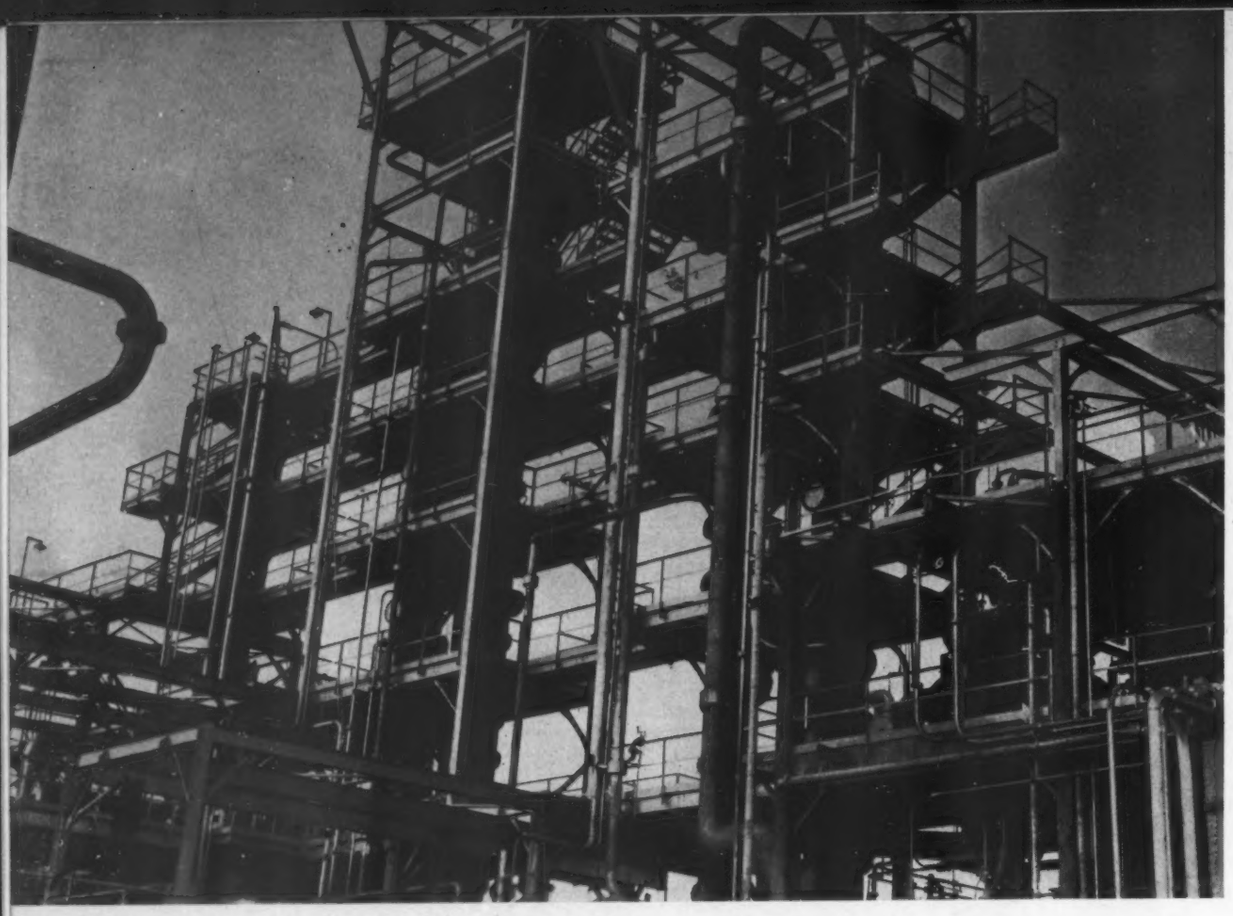


Synthetic Rubber and the Petroleum Industry

DR. M. B. HOPKINS, Standard Oil Development Company

UNTIL the war is over, secrecy requirements will prevent the telling of a complete story of what the petroleum industry is doing to make synthetic rubber available. The Baruch report submitted to Congress by the President, September 10, 1942, has done much to clear up confusion as to the nature of the country's rubber problem and the government program to solve it. It should be made clear at the start that no one company or industry is to dominate the giant new industry. The government has placed responsibility for carrying forward its rubber program in the hands of a long list of corporations representing the petroleum industry, the rubber industry, the chemical industry, and, more recently, the beverage alcohol industry.

Fortunately private industry with private capital had developed a small but well-established business in synthetic rubber before Pearl Harbor. As long as there was a supply of natural rubber from the Far East, there was little chance for the replacement of any large part of the natural rubber supply with synthetic rubber because of the higher cost of manufacturing the synthetic product. Chemists found, however, that some of the properties of the synthetic rubbers were superior to those of natural rubber. They stand up in services where rubber could not be used. They have plus value in manufacturing oil-resistant and heat-resistant rubber articles, such as gasoline hose, steam hose, cable and sheathing, belts, packings, seals, diaphragms, engine supports, printing rollers, gloves and garments, and many molded articles. By capitalizing their superior qualities a business was built up in synthetic rubbers for specialty purposes notwithstanding their higher cost. The total installed capacity for producing specialty synthetic rubbers in the United States at the end



Fractionation Equipment

of 1941 was about 20,000 tons per year. This compared with a United States natural rubber consumption of nearly 800,000 tons per year. The volume of synthetic was insignificant, but present ability to carry through an enormous government program to replace the entire natural rubber supply with synthetic is based upon experience in building and operating the small specialty plants.

Specialty Rubber Plants Before Pearl Harbor

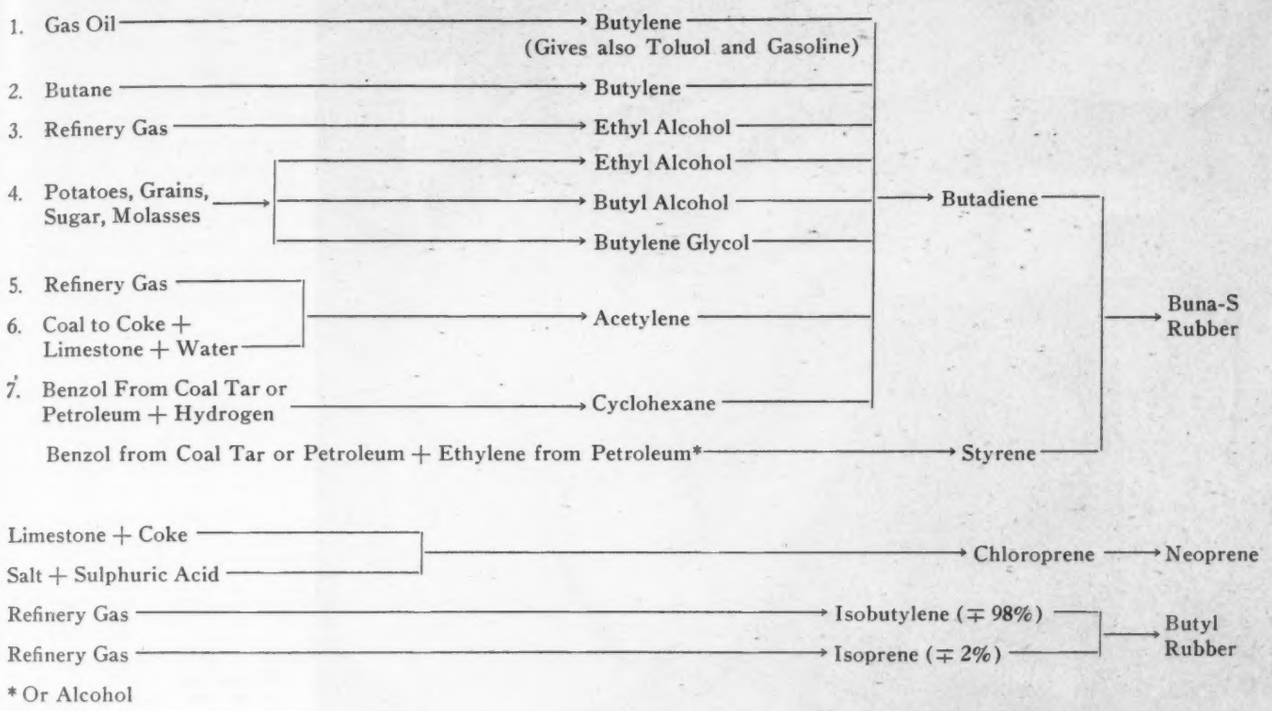
Standard Oil Company (New Jersey) announced as early as February, 1940, that upon the outbreak of war in Europe, it had taken over the entire ownership of the United States rights to the Buna type synthetic rubber which had originated in Germany. Standard had been interested in the Buna development for ten years. It recognized that in peace time and in the United States, where petroleum is abundant, oil is a more economical starting material for its manufacture than the coal used by the Germans or the grains and potatoes used by the Poles and Russians. Plants to make Buna-type rubber and the raw materials required for its manufacture were designed, built and put in operation by Standard in the spring of 1941. Ahead of this E. I. du Pont de Nemours & Company had developed over a period of ten years a flourishing business in its specialty product, neoprene. Firesone Tire & Rubber Company and United States Rubber Company had both been cooperating in the Buna development. Firestone was in production of Buna. The B. F. Goodrich Company had formed an affiliation with Phillips Petroleum Company for the production of synthetic rubber. Goodyear Tire & Rubber Company had built and was operating a small plant, obtaining its raw material from Dow Chemical Company. Standard Oil Company (New Jersey) had announced the discovery of a new type of rubber which it called "Butyl" and was building a $4,500,000 plant in which to produce it commercially. Carbide and Carbon Chemical Company was busily engaged in perfecting a process for making butadiene from synthetic ethyl alcohol derived from petroleum. Universal Oil Products Company and Shell Chemical Company were at work on processes for making butadiene directly from petroleum. Several other products had been developed with some of the properties of rubber but differing from rubber in that they canot be vulcanized to make the usual rubber articles. Thus Thiokol was made by Dow Chemical Company, Koroseal by The B. F. Goodrich Company, and Vistanex by the Standard Oil Company (New Jersey). Dow's Thiokol has subsequently been found to be a useful material for extending the life of tires by retreading.

The Government Program

Long before the first governmental action to provide rubber, the Army and Navy Munitions Board had recognized the plight in which the country would find itself if the war spread to the Pacific. Every available type of synthetic rubber was being quietly evaluated. When the National Defense Advisory Commission was created, the board had ready for this new agency all the basic facts on synthetic rubber. After the collapse of France in June, 1940, the first plan for government rubber plants was worked out. The purpose of these plants was to solve the many technical problems which remained in connection with large-scale manufacture of the raw materials under American conditions, the production of the rubber, and the fabrication of the rubber into tires. It was intended that this plan could be expanded to a scale sufficient to take care of the war requirements of the country. There has been much discussion as to whether this original plan was adequate to meet the need and whether the government agencies acted with rasonable promptness in carrying it forward, but that is now water over the mill.

The product known as "Buna-S" was from the

Simplified Chart Showing Preparation of Vulcanizable Synthetic Rubbers

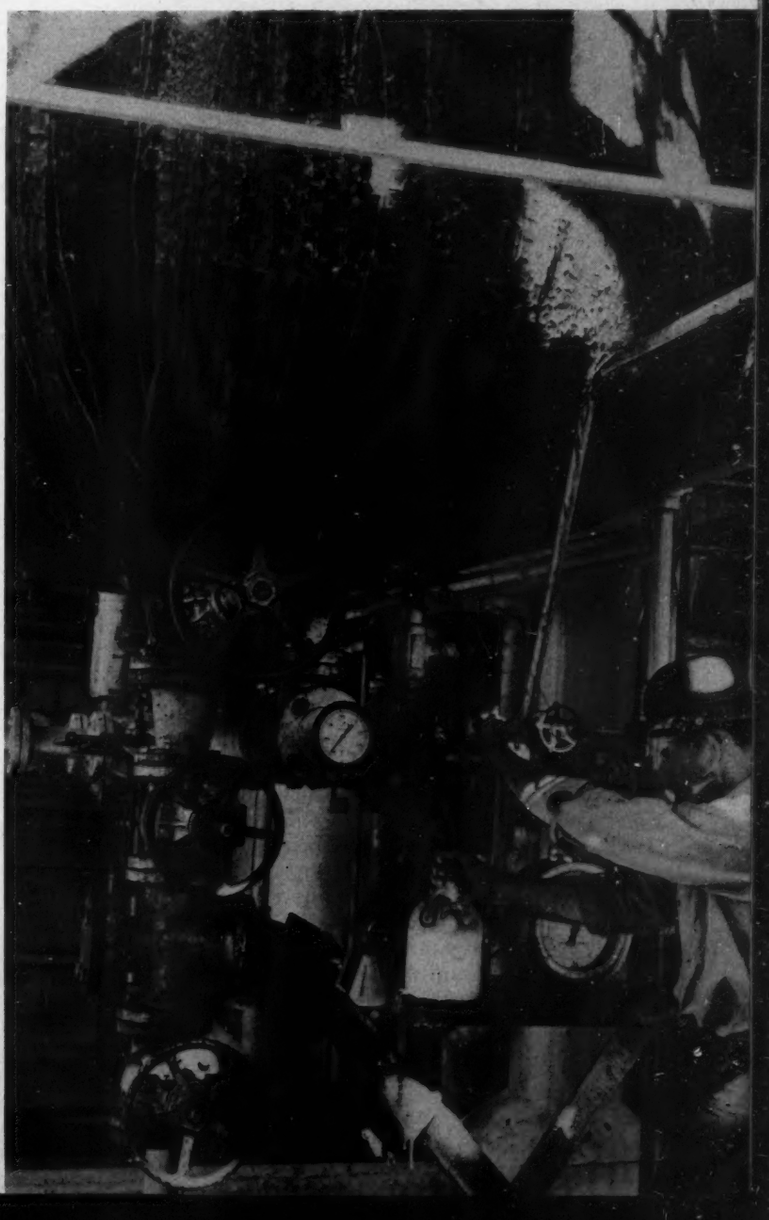


start agreed upon by the government and industry generally as the product best suited to constitute the main supply in the government program. This selection was made because of the potential availability of necessary raw materials, probable cost and demonstrated suitability for tires. Five American rubber companies had in 1939 and 1940 experimented with samples of Buna-S which Standard Oil Company (New Jersey) arranged to obtain from Germany in 1938.

The government rubber program, as fixed by the War Production Board in July, 1942, called for the production of 886,000 tons total annual output. The Baruch Committee recommended that this output be increased to 1,106,000 tons. The rubber types and quantities making up these figures are as follows:

	W.P.B.	Baruch Com. Addition	Total
Buna-S	705,000 Tons	140,000 Tons	845,000 Tons
Neoprene	49,000 (9,000 private)	20,000	69,000
Butyl	132,000	.....	132,000
Thiokol	.....	60,000	60,000
	886,000	.....	1,106,000

Buna-S is made from the two substances—butadiene and styrene. Neoprene is made from chloroprene, a chemical product derived from limestone, coke, salt and acid. Butyl rubber is made from the refinery gases—isobutylene and isoprene. Thiokol is made from diethylene glycol and polysulphide. The accompanying chart, showing the starting raw ma-



Polymerization of Butadiene with other chemicals results in a Latex type of fluid similar to the liquid taken from the Hevea tree. Here a sample is being taken for testing to determine that polymerization has been effected in the reactor.

Polymerized Latex is next mixed with acids for coagulation. Here the product is in the slurry stage after acids have been removed by washing and is ready for filtering. It will subsequently emerge as rubber crumbs which in turn will go to a milling machine to become sheet rubber.

terials for making Buna-S, Neoprene and Butyl lists seven different ways of making butadiene.

Much of the confusion about synthetic rubber arose from a lack of appreciation of the fact that Buna-S rubber was exactly the same product whether made from butadiene derived from oil, grain, coal or whatever source.

It was quickly recognized after Pearl Harbor that the government should go beyond the companies who had originally sponsored the synthetic-rubber business and utilize the services of technical organizations of other petroleum and chemical companies who up to that time had not participated in rubber activity. Accordingly, the government called in additional oil and chemical companies who were in a position to contribute technical service and managerial ability.

Responsibility for the production of neoprene, Butyl rubber and Thiokol has been placed by the government with the originators of these products. Du Pont will build the neoprene plants; Standard Oil Company (New Jersey) companies will build the Butyl rubber plants; and Dow will build the Thiokol plants. On the other hand, responsibility for Buna-S is divided among a large number of corporations. The rubber industry is made responsible for the final conversion of the butadiene and styrene to rubber and Standard's plant design and operating process has been made fully available to this group. The raw materials, butadiene and styrene, are to be manufactured in plants built and operated by the petroleum and chemical industries. The chemical industry will obtain its butadiene starting material, ethyl alcohol, from the industrial and beverage alcohol industries. The companies participating in the program as announced by the War Production Board and the Rubber Reserve Company are:

Goodyear Tire & Rubber Company.
The Firestone Tire & Rubber Company.
The B. F. Goodrich Company.
United States Rubber Company.
E. I. du Pont de Nemours & Company.
Koppers United Company.
Carbide and Carbon Chemicals Corporation.
Shell Chemical Company.
Atlas Oil Company.
Standard Oil Company of Louisiana.
Humble Oil & Refining Company.
Imperial Oil Company Limited (Canada).
Neches Butane Products Company (Gulf, Texas, Magnolia, Pure, Atlantic.)
Sinclair Rubber Inc.
Cities Service Refining Company.
Phillips Petroleum Company.
Sun Oil Company.
Southern California Gas Company.
Rubber Synthetics (Indiana, Sinclair, Cities Service).
Dow Chemical Company.
Monsanto Chemical Company.

The petroleum industry is concerned primarily

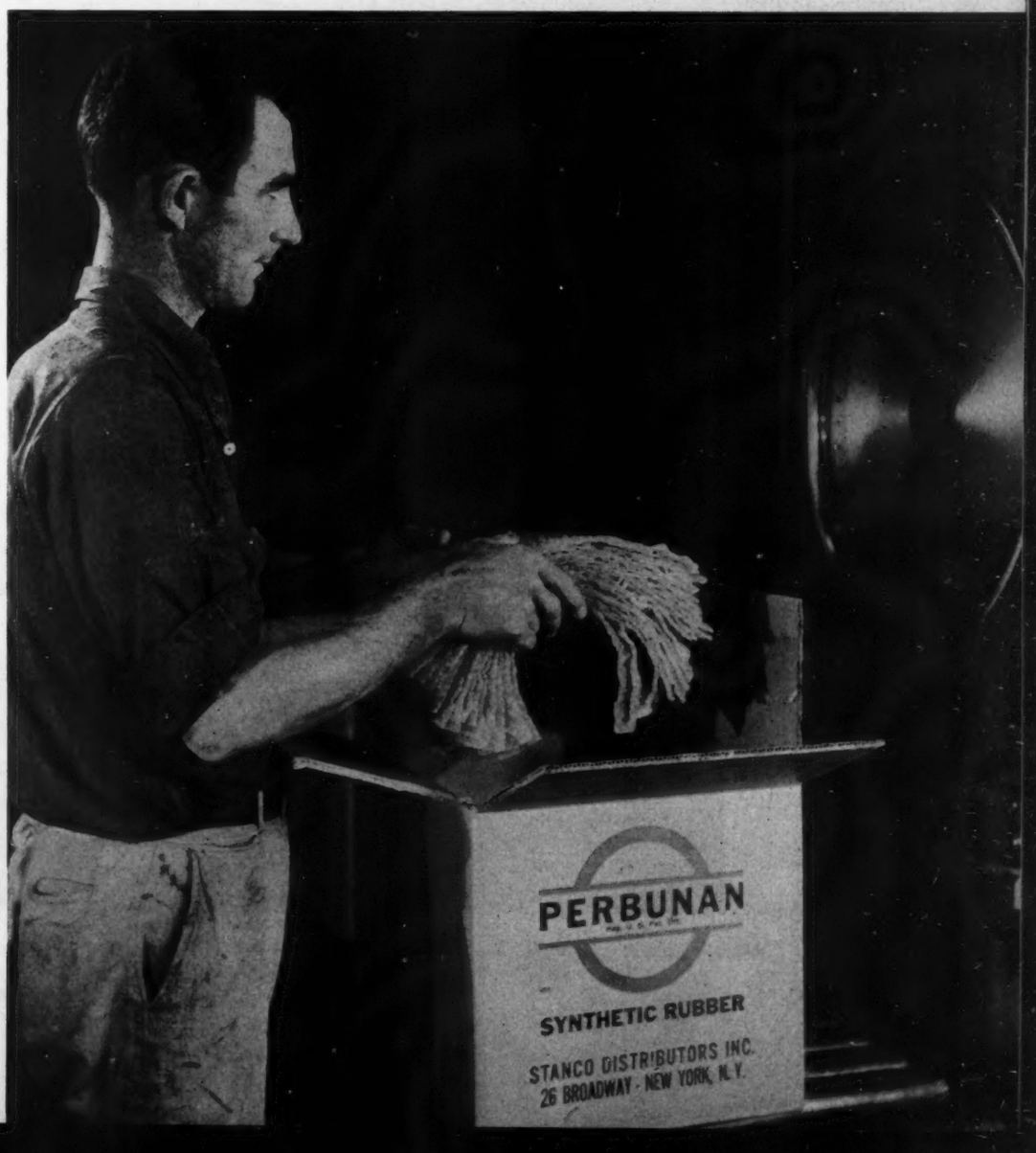
with the petroleum ingredients which go into synthetic rubber. These are butadiene and styrene to make Buna-S and isobutylene and isoprene to make Butyl rubber. From the standpoint of plant construction and quantity of structural materials required, as well as from the standpoint of cost and possible operating difficulties, manufacture of raw materials constitutes the major part of the rubber program. Responsibility for it is divided between the alcohol processes of the chemical industry and the petroleum processes of the oil industry. Turning again to the Baruch report, the following figures are quoted to indicate the source of butadiene for the indicated quantities of Buna-S.

SOURCE OF BUTADIENE	Tons of Buna-S Scheduled by War Prod. Board	Tons of Buna-S Recommended by Baruch Com.
1. From alcohol by the Carbide & Carbon Chemical Process, rated capacity	242,000	272,000
2. From butane (in natural gas) by a process developed by the Phillips Petroleum Co	50,000	50,000
3. From butane by the Houdry process	16,500	16,500
4. From butylene (obtained by the cracking of petroleum) by a process developed by Standard Oil of New Jersey	283,000	283,000
5. By the cracking at high temperatures of gas and heavy oils (the so-called thermal or refinery conversion process)	20,000	130,000
6. By combination of (4) and (5) in one locality	93,500	93,500
	705,000	845,000

Before Pearl Harbor, it was a question of which raw material would give the lowest cost rubber—oil, coal or farm products. A choice depended upon the local situation. In the United States where petroleum is abundant, oil was the most economical starting material. The Germans used coal because they did not have oil. In Poland, where farm products were more plentiful than either oil or coal, grains and potatoes were used. In Russia also farm products were the main raw materials. Now, however, war makes it necessary to cast aside the usual economic considerations and go about making rubber in the way which will give the quickest results with the least consumption of strategic materials and man-power. Whether the raw-material producer works on the farm or in an oil refinery is of secondary importance. Obviously, alcohol should be used regardless of cost to the extent that existing industrial and beverage alcohol plants make its use, rather than oil, a smaller drain upon strategic building material supplies.

Butadiene From Petroleum

The relatively small volume of butadiene consumed in the original small specialty rubber plants was all derived from petroleum. It was obtained as a low percentage constituent of gases resulting from cracking under high temperature and low pressure conditions which would yield some butadiene along with other products. This is basically the process



Sheet rubber is cut according to packing requirements for shipment to processing plants. Perbunan, a trade name for Buna N Rubber, is a specialty product with a variety of uses and replaces rubbers that can be used for tires.

Courtesy, Standard Oil Company (N. J.)

which is now to be used in the so-called "quick" butadiene production which the Baruch report refers to as "thermal or refinery conversion processes." The operation of the process is relatively costly and under normal conditions it could be used to only a limited extent because of the attendant production of large quantities of other undesired products. It has the merit, however, of utilizing existing refinery equipment which may be converted with only minor use of new strategic materials.

Except for the small amount of butadiene made by this thermal process, all of the production under the government program is to be made by the catalytic dehydrogenation of butylene. In the Phillips and Houdry processes, the butylene is produced from butane by dehydrogenation. Butylene is, however, a constituent of all cracked refinery gases. Standard Oil Company (New Jersey) developed methods of operating its fluid-catalyst cracking process in such a way as to make available further large supplies of butylene, thus avoiding in most cases any necessity of installing equipment to dehydrogenate butane. This fluid-catalyst cracking process is quite flexible and can be operated to produce varying proportions of 100-octane aviation fuel, motor gasoline, toluene for TNT, butylene for butadiene and isobutylene for Butyl rubber. Standard's butadiene process starts with butylene obtained as a co-product in cracking to make motor fuels.

There are a number of ways of going about the conversion of butylene to butadiene. The butylene can be thermally cracked to butadiene. A poor yield of the desired product is obtained in this way. The butylene may be first chlorinated and then converted to butadiene by heating to split off hydrochloric acid. This is an excellent method but the chlorine supply of the country does not permit its large-scale use in war time. All of the processes to be used in the main government program split off hydrogen from butylene by passing it over a heated catalyst. There are variations in catalyst, plant design, and operating conditions to produce butadiene from butylene in this way. So, also, the recovery and final purification of the butadiene will be by different processes in the different government plants.

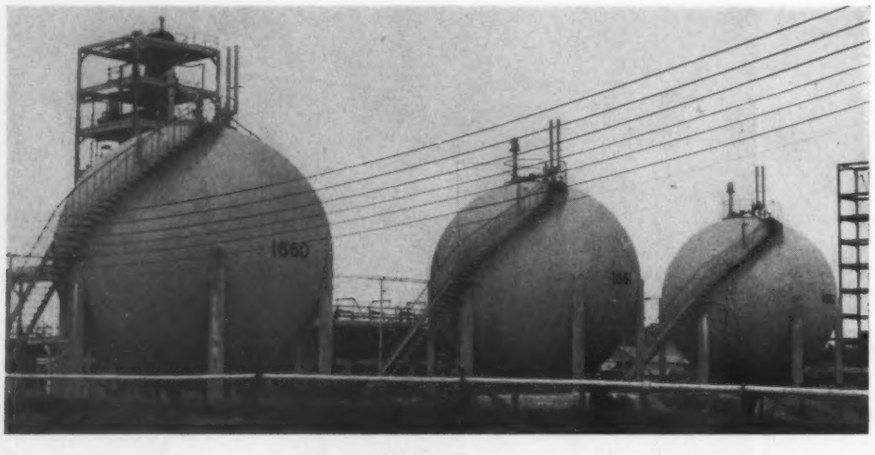
Styrene

In making Buna-S, one part by weight of styrene is used for each three parts of butadiene. Styrene production is therefore an important part of the rubber program. Prior to the present emergency relatively small quantities of styrene were produced in the United States for use in making a resinous material known as poly-styrene. Chemically it consists of a benzol ring to which is attached an ethylene group. In its manufacture benzol, derived from coal tar, is first treated with ethylene to produce ethyl benzene. This material is heated over a catalyst to split off hydrogen from the ethyl group thus producing ethylene benzene, or styrene. Ethylene for this reaction may be obtained by dehydrating ethyl alcohol or it may be produced by cracking petroleum gases. Under the government program most of the ethylene is to be made by the thermal cracking of propane gas and fractionation of ethylene from the resulting mixture.

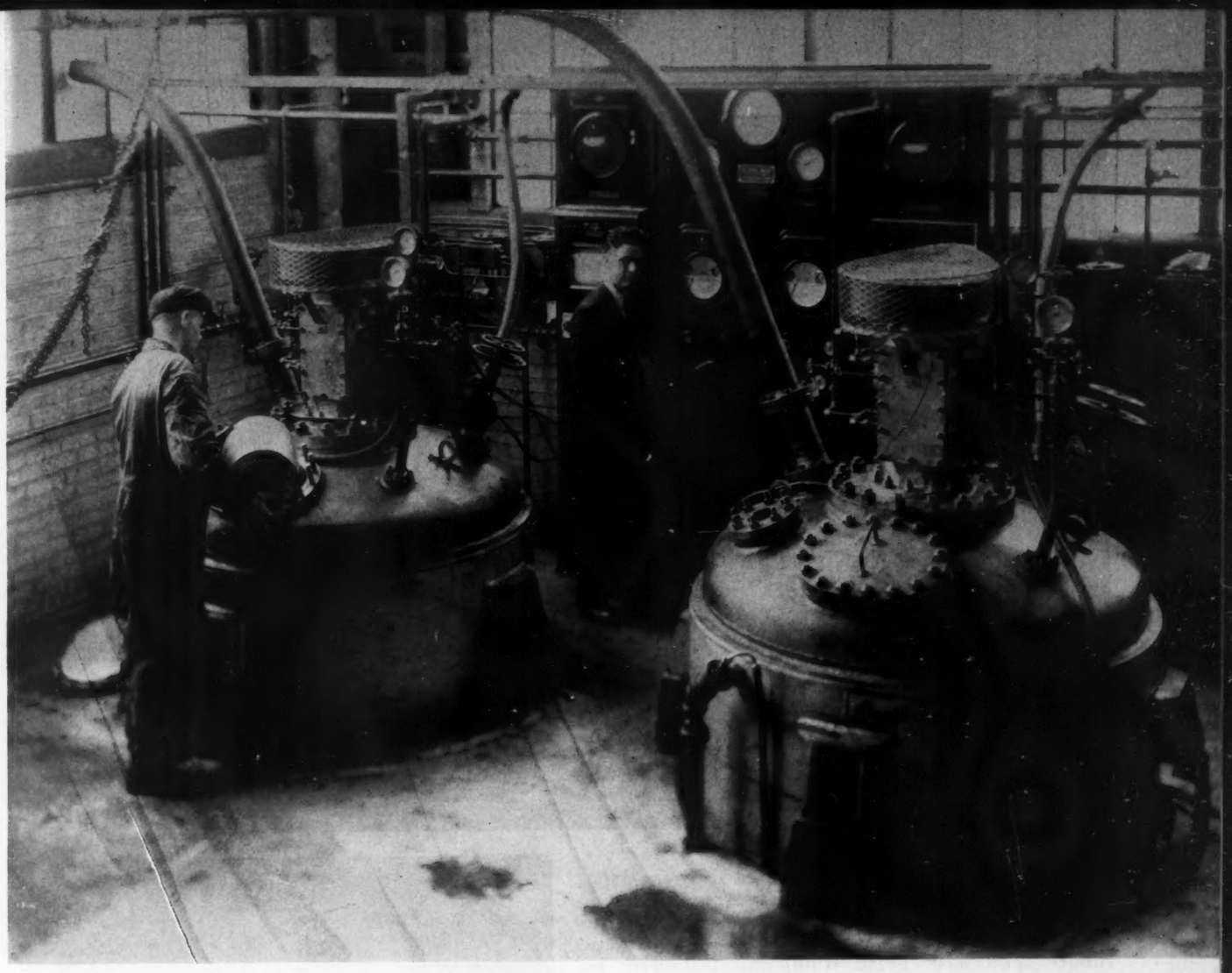
Butyl Rubber

As is now quite generally known, Standard's Butyl rubber, of which 132,000 tons per year are to be produced, is a copolymer of a very small proportion of a diolefin (about 2 percent) with isobutylene. The preferred diolefins are butadiene and isoprene. Isoprene is a constituent of the gases produced along with butadiene in thermal-cracking operations. It is also made from turpentine. Isobutylene for the government rubber program is to come from cracked refinery gases in which it occurs mixed with butane and butylene described above as the starting material for making butadiene. As in the case of butylene, isobutylene is an important material for making aviation gasoline but the fluid-catalyst process of Standard Oil Company will greatly increase the supply of both of these gases for rubber as well as aviation fuel.

The actual volume of petroleum to be consumed in manufacturing rubber is relatively small. It has been estimated that petroleum raw materials to be supplied for rubber production will be only 0.3 percent of the volume of crude oil production in the United States. Perhaps the greatest contributions of the petroleum industry to the rubber program have been, first, the foresight of some of its leaders in preparing to make synthetic rubber, and then the supplying of technical organizations, chemists, chemical engineers, designing engineers, construction engineers and management personnel. These organizations, along with the organizations from the chemical and rubber industries will build in a matter of two years an industry to replace a natural rubber development extending over more than a half century.



Butadiene Storage



Synthetic and Natural Rubbers

DR. H. L. TRUMBULL, The B. F. Goodrich Company

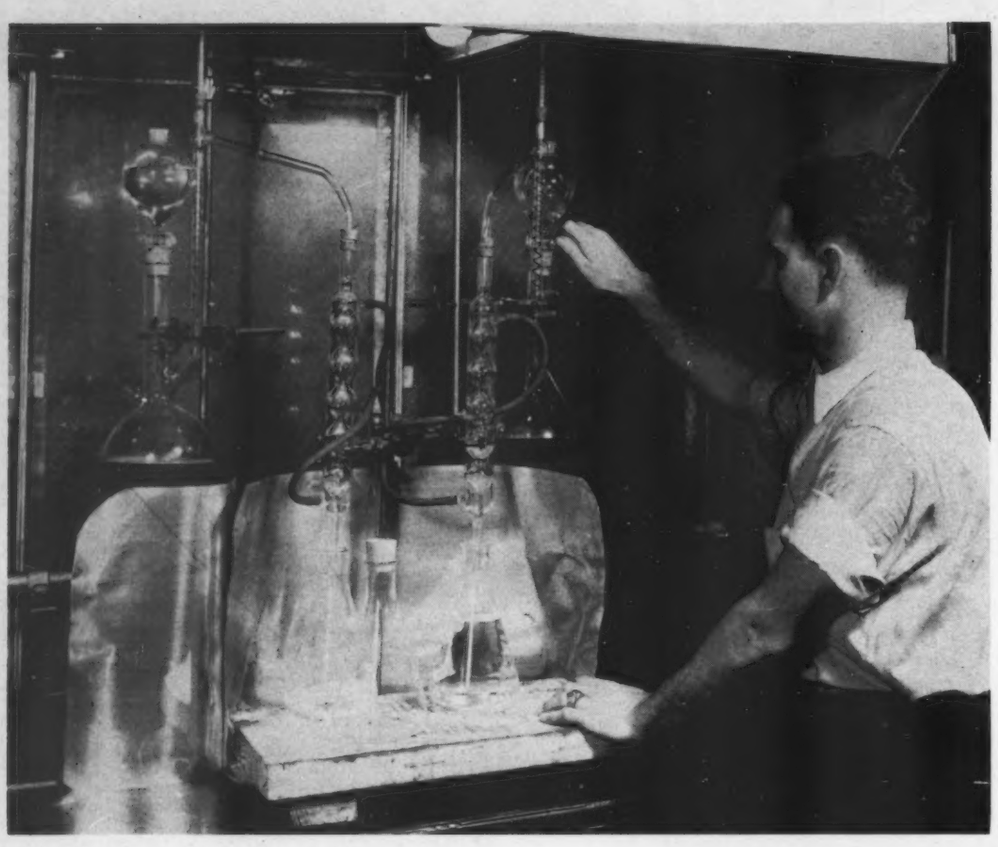
THE manufacture of rubber goods in America has increased tremendously since the advent of the automobile, requiring that more than half the world's natural rubber be sent to our shores in normal times.

American scientists and engineers have pioneered successfully most of the vital developments in the industry. The Yankee inventor, Charles Goodyear discovered vulcanization. Contemporary chemists have introduced chemicals which accelerate vulcanization and protect rubber goods from early failure due to oxidation. They have vastly improved rubber compositions in respect to abrasive wear, oil resistance and heat resistance. They have introduced improvements in compositions which insulate against electricity, shock and vibration. They have converted rubber into derivatives which have interesting applications, and in more recent years, they have even synthesized rubber-like compositions which, in many important properties, excel rubber itself.

Contemporary engineers and scientists have made rubber an imperative component of every vehicle of transportation, of every means of communication, of every mine, mill and factory installation in our complex industrial world. Yet, the American industry has been dependent throughout its whole history upon supplies of natural rubber which originated outside this country.

You have read that 97 percent of our crude rubber

The picture: **Butadiene and other ingredients are agitated in a soap solution under pressure, which creates a material with molecular structure similar to natural rubber.**



Minor products for polymerization are purified by distillation before going into the vat.

supplies have been cut off or threatened by the Japanese since Pearl Harbor. You have read that our federal government is financing large factories to make hundreds of thousands of tons of synthetic rubber. You have heard conflicting testimony by experts, proposals by corporations whose plans are at variance with the main plan. Congress has even proposed a separate rubber coordinator to handle this problem. You have heard that rubber can be made from petroleum, from coal tar, from grain alcohol, from turpentine and even from garbage. You have been told repeatedly that this country affords inexhaustible supplies of rubber scrap which, by conversion into reclaim, will give an abundant source of retreading material for civilian tires. You have heard of Buna rubbers, the Butyl rubbers, the Ameripols, Neoprenes and Thiokols as man-made rubbers; you have heard of the Russian dandelion, guayule, milkweed and goldenrod as sources of natural rubber. In fact, you have heard so much that you are doubtless bewildered by what you read and by what you hear broadcast over the radio.

When the sound and the fury cease, we can look for the supply of our extensive rubber needs from three main sources, the government's production of synthetic rubber, the reclaiming of discarded rubber articles, and the growth of plants which produce natural rubber.

The recommendation of the Baruch committee was that no further substitutions be made in the synthetic-rubber program and that production of butadiene be expanded from both petroleum and alcohol to the extent of providing 1,100,000 tons of synthetic rubber per year. The President has said

Casings of Ameripol were made by the B. F. Goodrich Company in 1940 and sold to the American public.

that recommendations of the special committee will be carried out.

Synthetic Rubber

Chemists have known for over 50 years that the hydrocarbon which constitutes the bulk of natural rubber is a polymer of isoprene. This was revealed clearly in the publications of Tilden, an Englishman who found that a sample of liquid isoprene boiling at about the same temperature as ethyl ether, when allowed to stand on the shelf of his laboratory over a period of months became an elastic material of high elongation. This observation of Tilden's clearly foreshadowed the challenge to this country today of producing synthetic elastic materials from chemicals which can be made abundantly here. The source of isoprene most frequently employed by chemists has been either natural rubber or turpentine. Obviously there is no point in trying to synthesize an elastic material by starting with natural crude rubber. Decades of study have discouraged chemists from trying to derive large quantities of isoprene from scrap rubber. The limited supplies of pine resins and turpentines available as starting materials have been fantastically out of balance with the demand for the large quantities of elastic materials which we need in our huge rubber industry. Until the last few months, isoprene has not been a commercial product in this country, and therefore, the challenge which we face is to synthesize products showing appropriate physical properties, not a particular chemical composition. In other words, the synthetic rubbers which will be made are not strictly rubber. It is the behavior of the product under severe service which concerns us, not its chemical composition.

Before the first World War, chemists whose curiosity impelled them to study synthetic rubber proved resourceful in approaching a number of possible solutions of the problem from fairly abundant starting materials. The Russian chemist, Kondakov, demonstrated that ordinary grain alcohol can be cracked at high temperatures to yield some butadiene, a simpler relative of isoprene belonging to the same family which chemists call diolefines.

Butadiene has four carbon atoms with two olefinic double bonds typified by the formula:

$$H_2C = \overset{H}{C} - \overset{H}{C} = CH_2$$

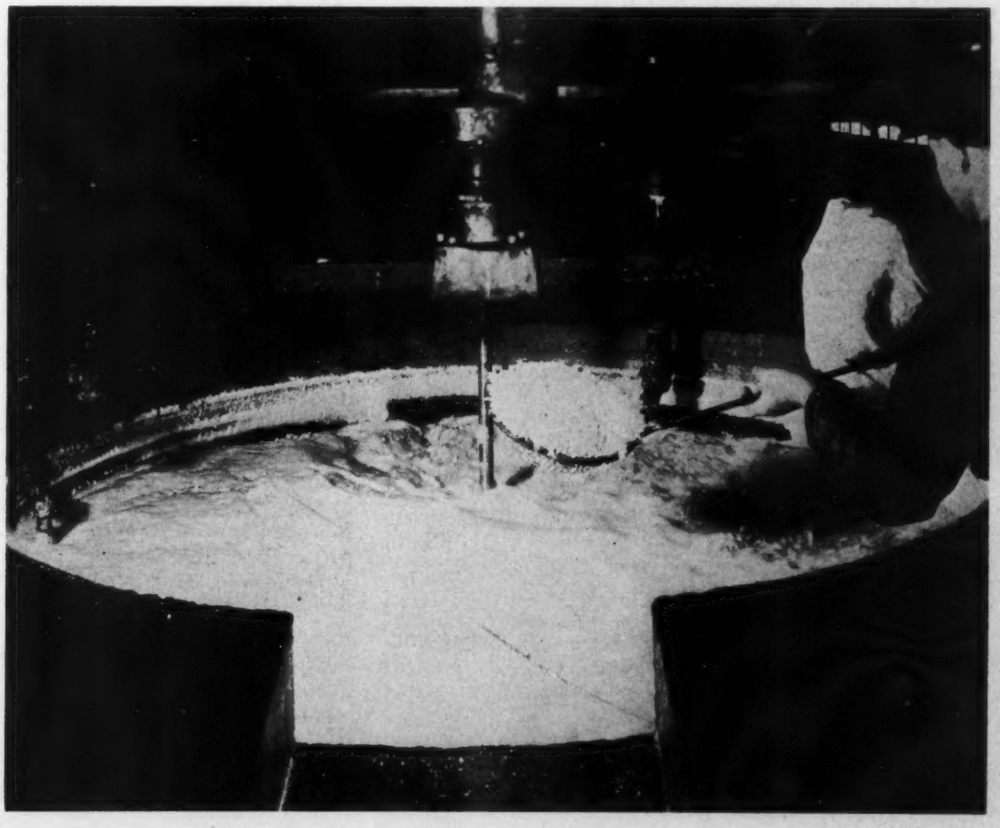
whereas, isoprene, a relative of butadiene, 2-methyl butadiene has the following structure:

$$H_2C = \overset{CH_3}{C} - \overset{H}{C} = CH_2$$

Another method of synthesis with alcohol as a starting point and resulting in the production of rather large yields of butadiene proved feasible in a four-step reaction.

1. Oxidation of alcohol to acetaldehyde.
   $CH_3 \cdot CH_2 \cdot OH \rightarrow CH_3 \cdot CH = O$
2. Condensation of acetaldehyde to acetaldol.
   $2CH_3 \cdot CH = O \rightarrow CH_3CHOH \cdot CH_2 \cdot CH = O$
3. Hydrogenation of acetaldol to 1, 3 butylene glycol.
   $CH_3 \cdot CHOH \cdot CH_2 \cdot CH = O + 2H \rightarrow CH_3CHOH \cdot CH_2 \cdot CH_2OH$
4. Dehydration of 1, 3 butylene glycol to butadiene.
   $CH_3 \cdot CHOH \cdot CH_2 \cdot CH_2OH \rightarrow 2H_2O + CH_2 = CH \cdot CH = CH_2$

The rubbers which were formed directly from the simple hydrocarbon butadiene were found by Kondakov and others to give a product far inferior to natural rubber in its elastic properties, and chemists



Polymerization results in a milky liquid, similar to the latex of the rubber tree. Its rubber content is solidified in another vat by acid coagulation.

Scrap improves some rubber products.

were for years inclined to avoid this starting material for that reason.

Just before the last war, the German chemists had discovered a method by which they could derive 2,3-dimethyl butadiene from acetone in fairly satisfactory yields and once having got this hydrocarbon, they perfected two methods by which they could convert it to a rubbery material. One synthesis, conducted at low temperatures for long periods, resulted in a soft rubber which the Germans called methyl rubber W (Weich, meaning soft). The other was operated at a higher temperature to give the methyl rubber H (Hart, meaning hard). H rubber was incorporated in ebonite compositions with high sulphur to give hard rubbers. Methyl rubber W was used to supplement natural rubber in all manner of soft rubber compounds including tires. During the last war, several hundred tons of the methyl rubbers synthesized from acetone as the starting point were made available to the German industry. These synthetic products proved far inferior to natural rubber for tires and tubes and were, therefore, not successful in replacing it. Because of the reputed superiority of the German scientists, their failure to solve this problem served to define it as extremely difficult.

French and British scientists in the first decade of this century had also arrived at a partial solution of the problem of synthetic rubber, but their efforts never became commercialized and for that reason did not gain much publicity.

None of the products of that period was really worthy of commercial use, so that after the last World War, crude natural rubber, which had for so many years proved to be the unique elastic material of commerce, held undisputed sway in the world markets. At the end of World War I the plantations in the Far East fostered by the British and Dutch produced increasingly large crops of rubber. The British Parliament invoked the Stevenson Act, a plan of rubber restriction. The inevitable consequence of this measure was to destroy the competitive market, and to enhance the price of natural crude rubber. Under managed economy, prices rose to a maximum of $1.25 a pound in 1925, but on the reverse swing of the economic pendulum, reached a low point of 2½ cents a pound by 1932, after the restrictions of the Stephenson plan were swept away.

This chaotic swing of rubber markets had a definite bearing on the problem of synthetic rubber. It challenged resourceful scientists to try to make from abundant starting materials large quantities of an elastic synthetic product to replace rubber.

Within the last two decades many interesting synthetic rubber-like materials have been made. In this country Patrick and Mnookin patented Thiokol, a condensation product of ethylene dichloride and sodium polysulfide. This plastic material comprises more than 80 percent by weight of sulphur and has found limited use in oil-resistant structures such as paint-spray hose, gaskets and sealing members. This year it has been proposed as a tire retreading composition.

Father Niewland, Notre Dame chemist, discovered chloroprene and its polymers. Chloroprene results from the union of acetylene and hydrogen chloride in the presence of catalysts. Its polymer, now manufactured by du Pont under the name Neoprene, has grown steadily in commercial importance for the past decade, and is now regarded as necessary to many important uses.

The chemists of The B. F. Goodrich Company have brought out Koroseal, the plasticized polymer of vinyl chloride, now being manufactured exclusively for military uses. Vinyl chloride is made by the direct union of acetylene and hydrogen chloride in a chemical reaction which obviously differs from that conducted by Niewland. The basic materials for

these polymers which carry chlorine are limestone, coke, salt and sulfuric acid.

Almost simultaneously with these developments in America, the German chemists were devoting their attention once more to butadiene as a starting material. This time, instead of polymerizing butadiene with itself, they introduced another ingredient, usually olefinic in character like styrene, and effected a copolymerization of these two ingredients. The term copolymer refers to the linked final products, long chains of a thousand or more carbon atoms and the term comonomer applies to the unreacted starting materials, butadiene and styrene respectively. The styrene copolymer of butadiene produced by the Germans proved suitable for tire rubber and became known under the trade name, Buna S. Oil-resistant compositions resulted when butadiene was polymerized with a suitable comonomer such as acrylonitrile. Many variants on this theme of copolymerization were brought by chemists working not only in Germany, but very fruitfully in our own country. Thus we can record beside the Buna rubbers, Ameripol, Chemigum and Butyl rubbers as products of American ingenuity.

It is now possible to predict that the research chemist of the future is going to produce definite compositions which best serve any specific use for which elastic qualities are required. Control of variables such as the components of the reactive systems, the catalytic agents to direct the reactions, and the energy factors pertaining to processes in modern equipment, insure that we can make in our factories elastic compositions which excel rubber for almost any given set of physical properties.

There will doubtless come synthetic compositions which excel natural rubber in tread wear, heat resistance, electrical resistance, permeability to air and other gases, flame resistance, resistance to ozone and oxidizing chemicals, resistance to swelling and penetration by oil. In fact, most of these objectives have already been reached by known compositions and there is no doubt that the essential need for crude rubber, based upon the superiority of its physical properties, is almost a thing of the past. In a free world market a few years from now, the use of natural rubber can be justified only because of economic considerations, not because of its superiority.

Butadiene, which is so important in this field, can be made either from petroleum or from fermented products of grain, one of which is alcohol. Normally, the choice of raw material starting point would be determined by competitive factors. Because of the prevailing shortages of strategic materials, these competitive factors do not prevail at present, and the choice of the starting material ties very closely into our military needs. You will appreciate, therefore, why no one can tell you whether it is better to make synthetic rubber from alcohol, from petroleum, from coal tar or from some other starting material.

Reclaimed Rubber

Rubber scrap is a composite structure of vulcanized rubber, fabric and metal. By reclaiming, the bulk of non-rubber components are eliminated, and the tough vulcanized rubber portion is softened to a plastic state suitable for use in the rubber factories. The metal portions of rubber articles are removed by hand and machine operations. The fabric is largely destroyed by heat and by digestion with chemicals in a process not detrimental to the rubber. The recovered rubber, softened by heat, and in some operations, by the use of reagents, is refined by extrusion through strainers and by passing through tight mill rolls to form sheets of plastic material. On a weight basis, the finished reclaim constitutes only little more than half of the starting material. The

Old casings are ground and the pulverized material put in a devulcanizer where caustics eat cotton from the rubber.

equivalent rubber content of the reclaim is again about half or perhaps a little more. Hence, in practical operation, from a given scrap pile is derived a rubber value equivalent to about one fourth its weight. For inner tubes this value will run higher, and for hose and matting, appreciably lower, but for old tire casings, which comprise the main tonnage, the rubber value of the reclaim is about one fourth of the scrap weight.

This does not mean that natural rubber is recovered from scrap, since reclaimed rubber is quite different in composition and characteristics. Reclaim has certain properties in which it excels, but its main use is to supplement either crude rubber or synthetic rubber in the manufacture of finished rubber goods. The reclaim production capacity of this country is about 300,000 tons, which may be increased to 350,000 tons. At the moment, reclaimed rubber is best regarded as a conserver of our precious stock pile of crude rubber. A few months hence it will doubtless be regarded as a conserver of synthetic rubber.

The actual process of unscrambling vulcanization, by which rubber scrap can be made into unvulcanized rubber has never been discovered. Practically, in the near future an entirely different problem requires solution. How are we going to reclaim synthetic rubber scrap? Each variety of synthetic rubber may require a different method.

Assuming that the rubber requirements of the United Nations aggregate 800,000 long tons each year for the next three years, the bulk of these requirements must come from synthetic rubber and reclaim, not from our dwindling stock pile of natural rubber. We have had years of experience in handling compositions made from reclaim and from natural rubber. We have less experience in large-scale handling of synthetic rubbers.

There is, however, a third avenue of approach to relief from the rubber shortage, the possible growth of plants from which rubber can be derived. For economic reasons our past experience has been principally with wild trees or plantations of domesticated trees in the tropics, from which the liquid latex was tapped as the starting point in preparing natural rubber for over-seas shipment. We are not now operating in a world-competitive economy. Over-seas shipments involve hazards and a large percentage of loss even from areas not controlled by our enemies. For that reason I wish to call your attention to a number of North American plants known to produce rubber.

In the studies of the late Thomas A. Edison, 17,000 plants representing some 1,700 species were investigated. Nearly all were found to contain some rubber. The Russians are said to have studied 100,000 plants in their search for rubber. The United States Bureau of Plant Industry has, for years, studied domestic plants and plants of foreign origin known to produce rubber. This bureau inherited Edison's experimental material, and has carried on certain phases of his progress along with studies which they have themselves initiated. They maintain a large collection of plants at Coconut Grove, Florida, for this study. They have a dozen or more tropical stations for studies involving the Hevea rubber and other tropical trees, and they have additional plant collections at Savannah, Georgia, and a number of other stations. Government scientists have made and are making valuable contributions in this field. At the Southern Regional Laboratories of the Department of Agriculture, dozens of investigators are studying the problem of how to derive useful rubber from Edison's goldenrod, a plant which can be propagated rapidly from both stolons and seed.

To grow rubber in this country in time to do any good in the war effort we need plants from which it can be derived as an annual crop. Doubtless many of you have been interested in trying to derive small amounts of rubber from roadside weeds. It can be done after a fashion if you have the patience to rub

Reclaimed rubber is kneaded under pressure on steam-heated rolls.

Slabs from reclaim are ready for manufacturing processes.

the latex between your fingers until a ball is formed. The milkweeds, the Indian hemp, the dandelion, wild lettuce and leafy spurge, certain varieties of goldenrod, for example, all contain rubber. It is quite another thing, however, to collect large enough quantities of rubber from any one kind of plant material to supply the huge tonnages required, and to refine the resulting product to an acceptable grade useful to the industry. In most of the plants which bear rubber, it is present in the form of latex, a milky exudate which when tapped from living specimens is invariably contaminated with other plant juices. These juices comprise proteins, resins, sugars and other carbohydrates, mineral salts in solution, and many other contaminating ingredients. Most frequently, the exudate consists mainly of non-rubber ingredients which not only dilute the rubber present, but may actually prevent it from displaying its characteristic properties.

The owners of Hevea plantations in the Far East and Africa for many years have been able to make a profit by selling rubber at eight cents a pound. Native estates in the Far East, in competition with the larger estates, were willing to bring rubber to Singapore for even three cents a pound. Under such a system it has been more profitable to study other problems than that of deriving rubber from domestic plants.

Now it becomes necessary to mass many simultaneous investigations to compensate for the lack of information on this subject. An extensive study is in progress in which hundreds of technical men in research effort in the universities, in the United States Department of Agriculture, in other government bureaus and in the rubber industry are collaborating to solve the many necessary problems connected with the growing of rubber.

We are no longer interested in how profitable the growth of rubber can be made, we are interested in winning this war. We need to pool all efforts promptly to produce a crop which we can control and which will yield abundantly each year from that store which Nature provides through photosynthesis. Our long favorable technical experience with rubber, our comprehensive knowledge of its technology and our intimate understanding of its properties makes us all the more eager to supply natural rubber if that can be made possible.

Ironically, since nearly all the world's rubber came from latex-producing trees, most progress has been made in this country in growing a plant that does not produce a flow of latex. This is the domesticated desert wildling guayule, which became a plantation crop through the 30 years' effort of Dr. W. B. McCallum. Dr. McCallum studied some 4,000,000 guayule plants and selected three from which to breed the stock which is being grown on the government plantation at Salinas, California. The United States Forest Service in this year's collection of seed is going to exceed their estimate of last spring about fivefold, which represents a quantity adequate to plant nearly a quarter of a million acres, and in five years, an amount of rubber equivalent to about 25 percent of our normal requirements, if optimum plans work out.

Despite the fine scientific work of McCallum and his associates, it is disappointing to note that the crop requires about five years from seed to a plant producing the maximum amount of rubber. Our need is so urgent that a five years' wait at this interval is critical. Studies aimed at shortening the productive period of guayule are actively under way, and in a few months we should know if this objective is practical.

The rabbit brush investigated in 1919 by the University of California scientists, which was found by them to contain rubber, grows in 10 states of the far West. It generally grows in sparse stands and

the plants contain relatively little rubber. Whereas, mature plants of guayule may carry as high as 20 percent, the rabbit brush rarely carries more than 1 per cent by weight of rubber. Accurate and comprehensive studies are being conducted in the United States Bureau of Agricultural Chemistry and Engineering, which, if successful, will justify harvesting available stands of this plant at an early date for the production of rubber from this source. But the scientists now estimate much lower yields than those first predicted by the botanists of the University of California. We may count ourselves indeed fortunate if 30,000 tons of rubber can be made from rabbit brush. In these woody desert plants, the rubber occurs mainly in the cortex and is derived by a mechanical ball milling process under water. The woody portions of the plant sink to the bottom and the rubber floats on top in a form known as "worms." These worms are further treated to free the rubber from mechanically held bark and fragments of woody tissue and thus refined for commercial use.

Latex-Bearing Plants

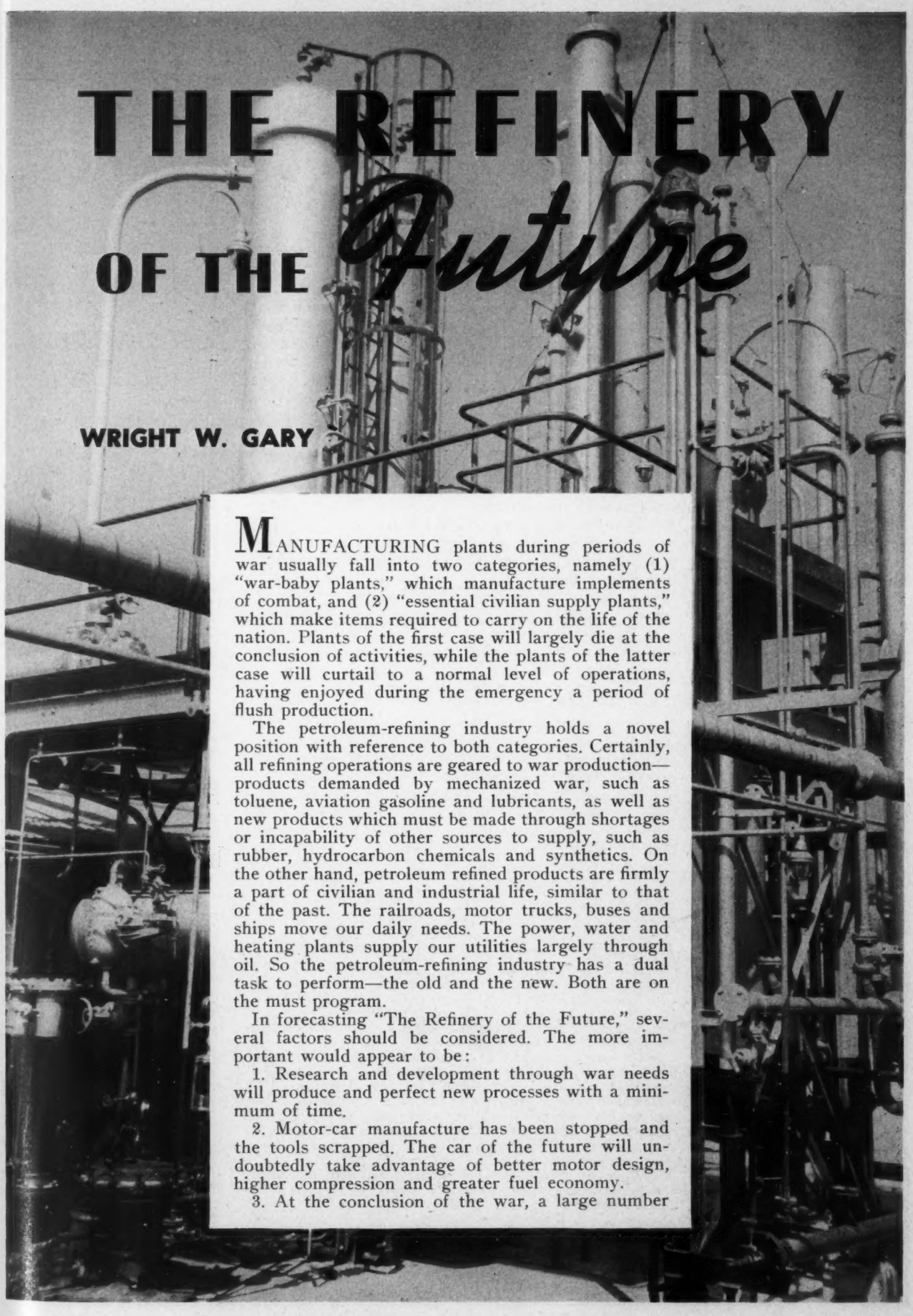
Domestic plants which bear latex far outnumber the desert varieties and there are certain possibilities that on this continent they may be made to produce rubber. It is interesting to note that in one of these, Edison's goldenrod, the rubber occurs primarily in the leaves; in another, the Russian dandelion, which is being grown experimentally here for the first time this year, primarily in the roots. In a third variety, a vine which grows in subtropical locations, the rubber is more evenly distributed in the leaves and stems. This plant, known as Cryptostegia grandiflora, constitutes an interesting possibility which is being extensively investigated. From it has been made rubber of good quality. How abundant Cryptostegia rubber can become is an active problem at present, engaging the attention of men in the rubber industry, in the government bureaus and laboratories, in the field stations where the introduction of plants is being studied, and by agronomists in our sister republics to the south. This plant is deemed to offer the best possibilities of rapid production of rubber of any of the latex-bearing species and will doubtless repay the diligent effort which is being invested in this study.

The latex-bearing domestic plants present a challenge to America which is not being neglected by her scientists. These plants alone cannot be expected to produce all of the tire rubber required, but we need every bit of rubber that our ingenuity can produce from all sources, and we need it promptly. Furthermore, it is of the utmost importance that all new sources of rubber which can be created remain subject to our control at all times.

By way of summary, an effective combination of the resources of this country including adequate financial backing, sound technical effort and the cooperation by business and the government seems to assure the eventual relief from our rubber shortage through the production of synthetic rubber under the government's program, the increased production of reclaimed rubbers, and the creation of new sources of natural rubber from plants which are growing and can be grown on this continent. This cannot, however, be construed as offering any immediate hope for rubber to be used for essential civilian requirements, since our military needs, coupled with those of our allies, bulk so tremendously.

Courtesy, United States Department of Agriculture.

Most success with rubber bearing plants in the United States has been with the guayule bush, which must be harvested.



THE REFINERY OF THE *Future*

WRIGHT W. GARY

MANUFACTURING plants during periods of war usually fall into two categories, namely (1) "war-baby plants," which manufacture implements of combat, and (2) "essential civilian supply plants," which make items required to carry on the life of the nation. Plants of the first case will largely die at the conclusion of activities, while the plants of the latter case will curtail to a normal level of operations, having enjoyed during the emergency a period of flush production.

The petroleum-refining industry holds a novel position with reference to both categories. Certainly, all refining operations are geared to war production—products demanded by mechanized war, such as toluene, aviation gasoline and lubricants, as well as new products which must be made through shortages or incapability of other sources to supply, such as rubber, hydrocarbon chemicals and synthetics. On the other hand, petroleum refined products are firmly a part of civilian and industrial life, similar to that of the past. The railroads, motor trucks, buses and ships move our daily needs. The power, water and heating plants supply our utilities largely through oil. So the petroleum-refining industry has a dual task to perform—the old and the new. Both are on the must program.

In forecasting "The Refinery of the Future," several factors should be considered. The more important would appear to be:

1. Research and development through war needs will produce and perfect new processes with a minimum of time.

2. Motor-car manufacture has been stopped and the tools scrapped. The car of the future will undoubtedly take advantage of better motor design, higher compression and greater fuel economy.

3. At the conclusion of the war, a large number

of planes will be available for civilian travel and world-wide freight. A younger generation will exist that likes and knows how to fly. Plane plants will have enormous facilities for manufacture.

4. New petroleum products will have been produced through war needs which can be quickly converted into peacetime civilian uses. Such products include synthetic rubber, plastics, solvents and hydrocarbon chemicals.

5. During World War II, the United States is the "supply depot" of the world. Areas of combat are drastically bombed. Petroleum refineries outside the United States are being destroyed and are not being replaced, either due to location or lack of construction materials. At the end of the war, it would appear that American refineries will be producing 95 percent of the world's supply of aviation fuel and 90 percent of the synthetic rubber. Hydrocarbon chemicals will be by-products in large volumes with processes available for cheap manufacture.

Present conditions and requirements are changing, but certainly the trend is well defined. The indications are, that the "Refinery of the Future" will comprise:

a. A combination oil refinery and chemical plant.

b. Equipment suitable for high-temperature thermal conversion.

c. Catalytic equipment capable of high yields and octanes.

d. Polymerization equipment for combining low-molecular-weight hydrocarbons into desirable liquid products.

e. Extraction equipment for separations not possible by fractionation.

The refinery of tomorrow will be extremely flexible. A combination of operating units will permit a wide variety of products and yields. These will be dictated by a broad field of varying demands. New markets will be created. The general effect should be that refineries will become less competitive, each refiner becoming a specialist in some branch of manufacture. Motor gasoline as known today will become a secondary source of revenue.

☆

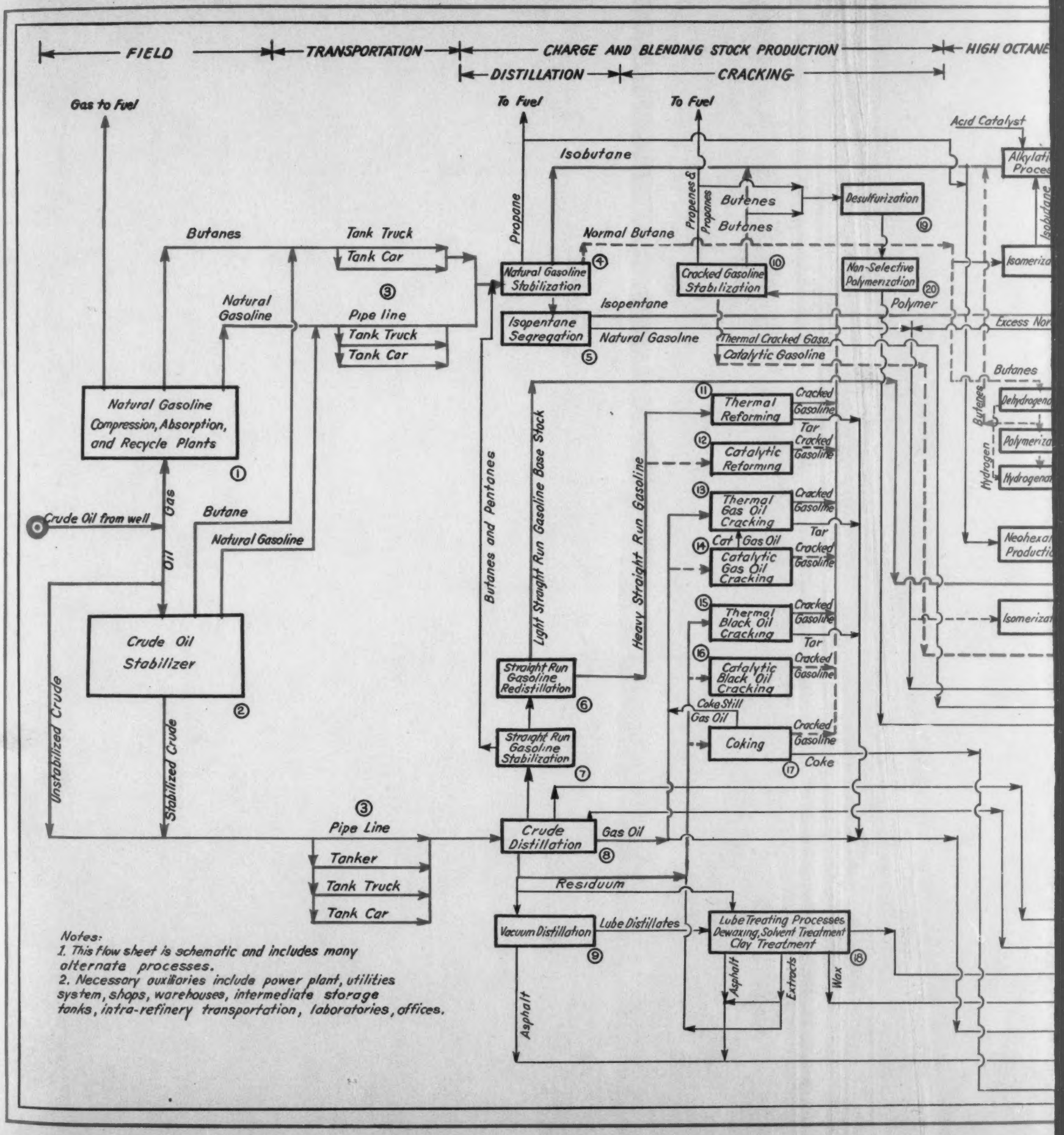
WHILE WRIGHT W. GARY, now president of Filtrol Corporation, was Director of Refining, Office of the Petroleum Coordinator for War, he insisted that the manufacture of war products should be spread to the whole industry. This viewpoint was responsible for bringing the output of 100-octane aviation gasoline ahead of its early schedule.

When butadiene became a refining task he carried this attitude into the synthetic-rubber program. Now more butadiene from more sources is the bright spot of butadiene manufacture.

Now that refining promises to become a chemical processing industry his prediction is that the future plant will be a source of chemicals as well as gasoline and fuels. Further he points out the opportunity for each refiner to become a specialist in some one product.

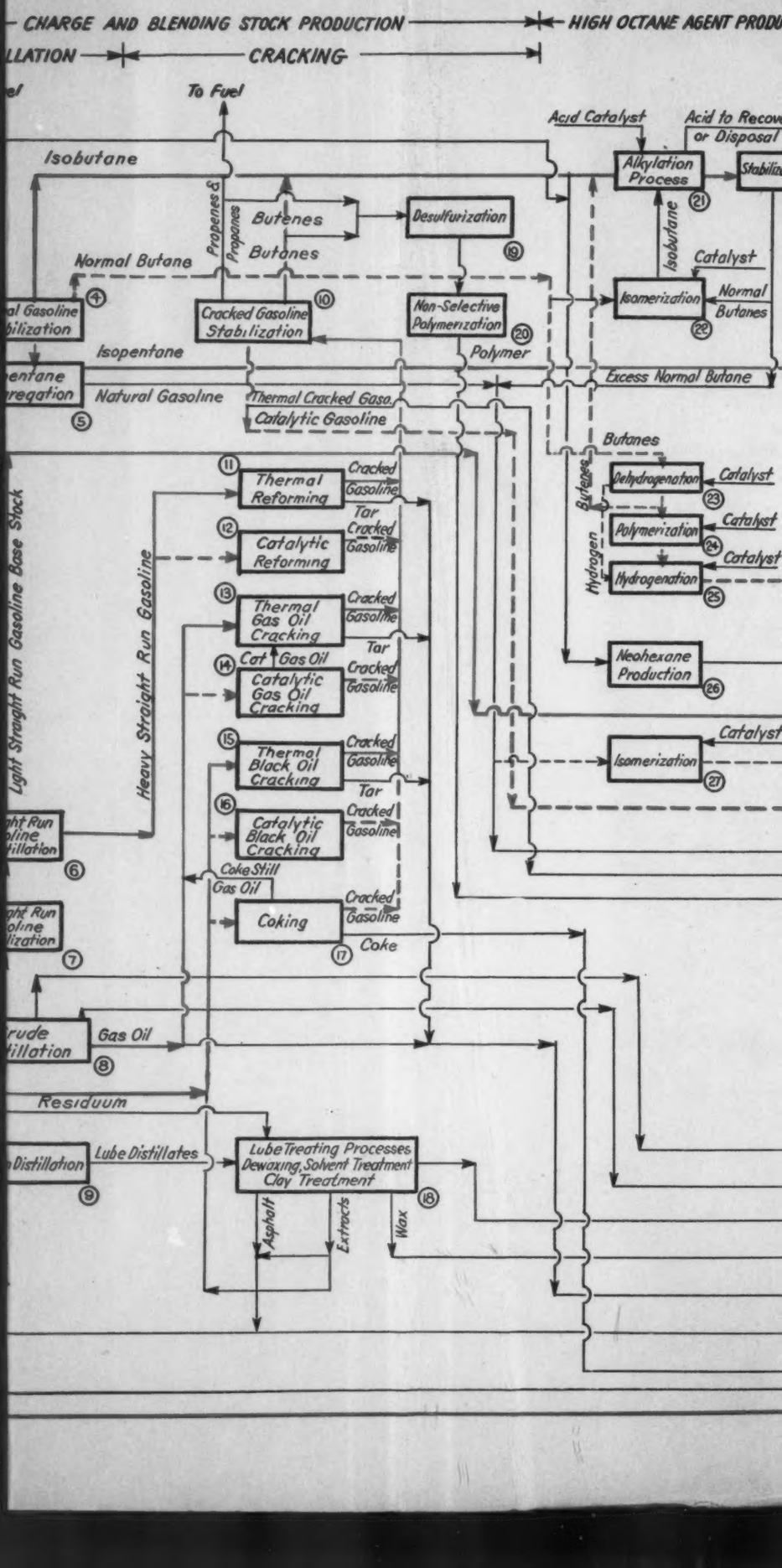
The smaller plants have opportunity here, since the reward will be on technical knowledge and quality of products rather than on volume.

Diagramatic Flow Sheet Illustrating Processes Related to P

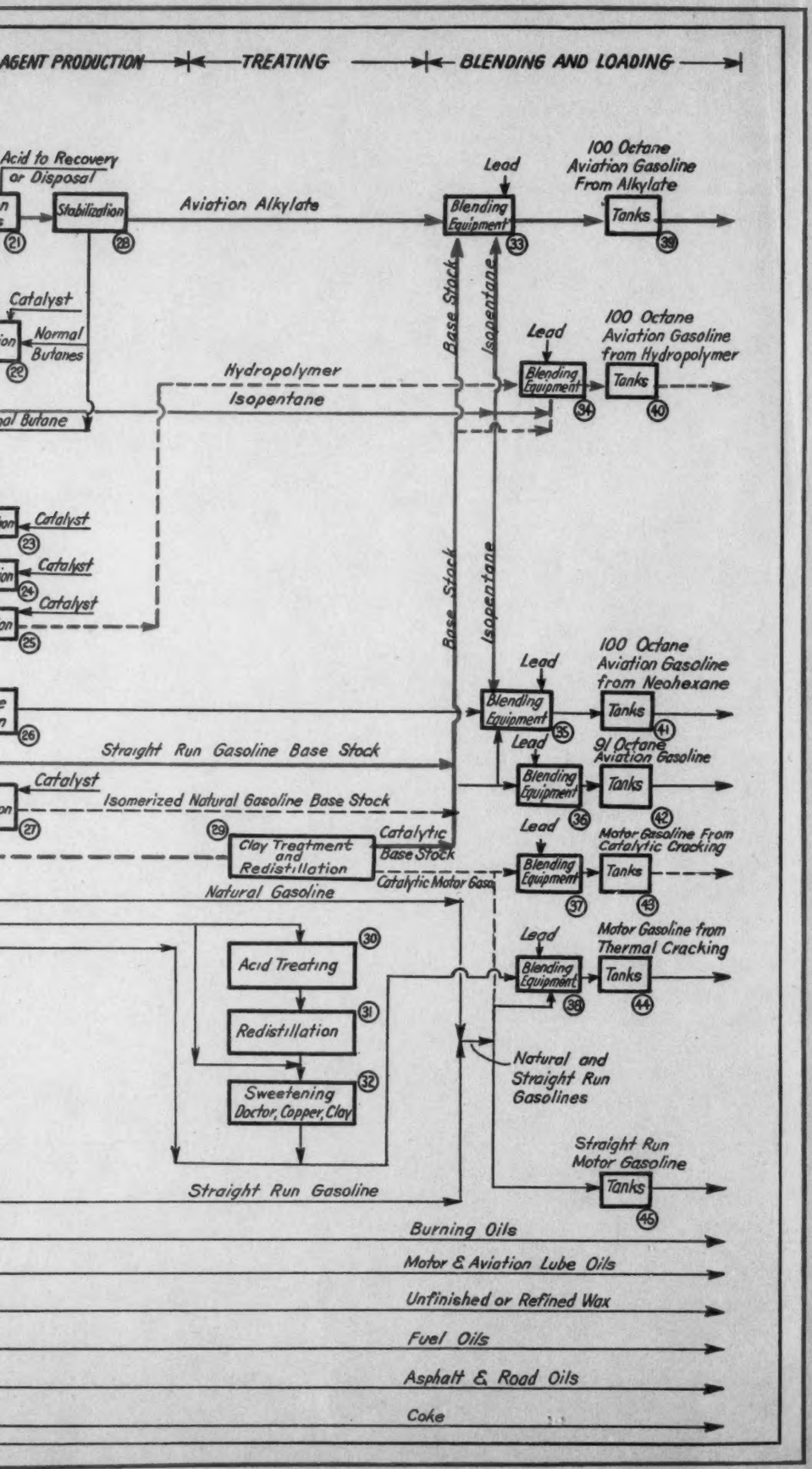


Notes:
1. This flow sheet is schematic and includes many alternate processes.
2. Necessary auxiliaries include power plant, utilities system, shops, warehouses, intermediate storage tanks, intra-refinery transportation, laboratories, offices.

llustrating Processes Related to Produ



roduction of Aviation Gasoline



THIS flow diagram was prepared in the office of the Petroleum Coordinator for War when stress was on increasing the output of 100-octane aviation gasoline. It is a composite scheme for combining natural gasoline and crude oil as the charge to one plant whose thermal and catalytic units would provide base stock while isomerization, polymerization and alkylation units would provide higher-octane hydrocarbons, while blending would provide two grades of aviation gasoline as well as motor fuel of catalytic source and motor fuel of thermal-cracking source.

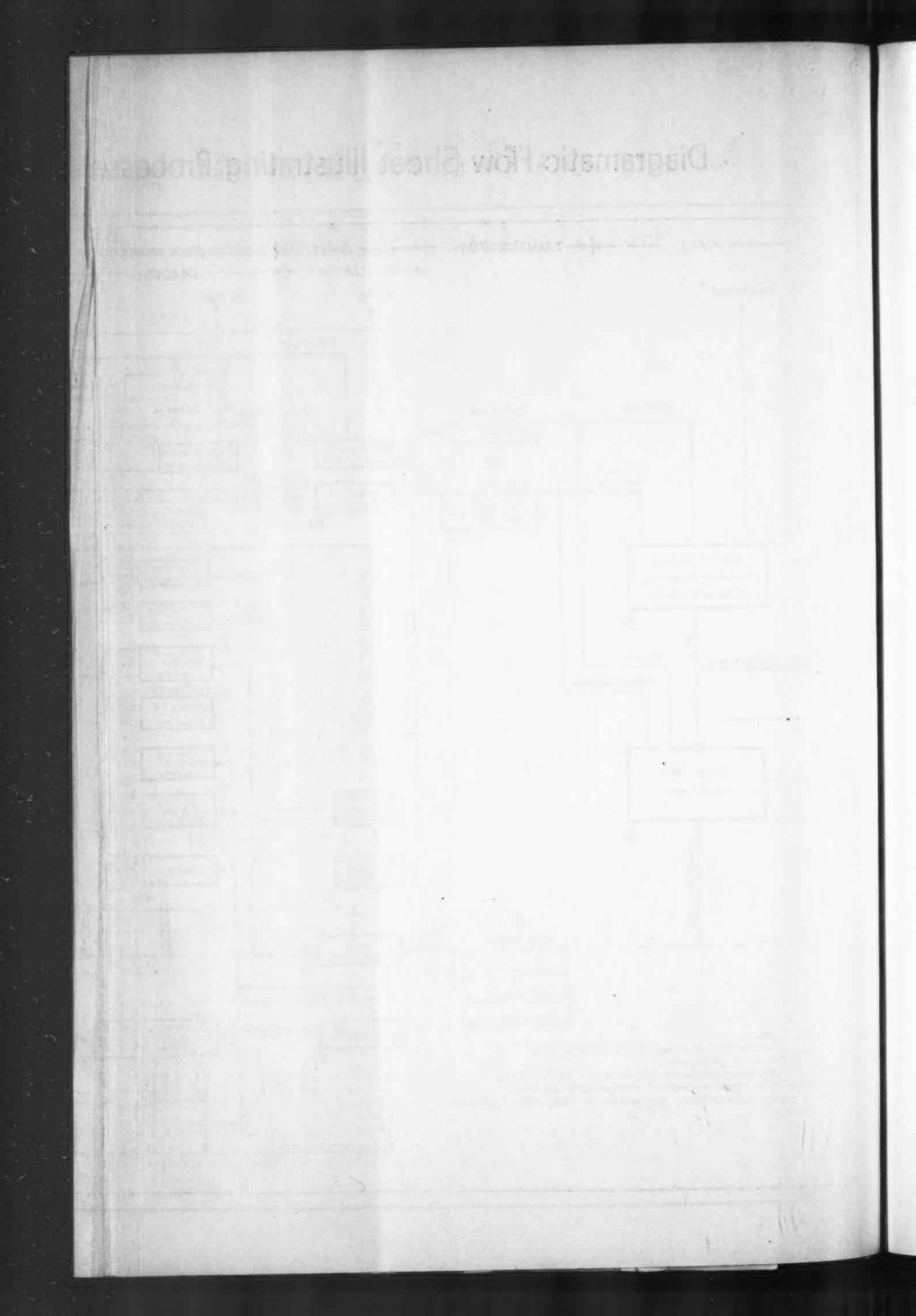
A similar flow diagram, drawn in the light of the need for synthetic rubber ingredients, would provide either catalytic or thermal cracking units, into which would be charged all or part of the butane and butylene for conversion to butadiene. This unit would include a purification process in which the proper solvent would release other hydrocarbons from butadiene.

The linking together of available routes to aviation-grade gasoline was a method of revealing how this product was of necessity tied into basic refining. Although no one plant may include all the processes offered, the diagram is significant in that it still represents a composite picture of the large refining plant of the future. Adjustment between available processes would give such a plant flexibility in output of either high yields of burning oils or of motor fuels.

By deliberately operating thermal units for high yields of butanes or butylene feed for butadiene could be produced without disturbing the lighter hydrocarbons essential to aviation grades of gasoline.

After stabilization of crude, 1 to 3, crude distillation provides unstabilized gasoline for further processing and residuum for lubricating oils. Then by cracking and reforming of all cuts from the crude-oil-distillation unit the combined stream of cracked distillate is ready for stabilization, operations 10 through 17. After treating and redistillation the cracked gasoline is available for blending with the straight-run base stock and the products of isomerization, polymerization and dehydrogenation to give the desired gasoline. Tetraethyl lead is accepted for all gasoline grades.

Across the top of the diagram are the steps for processing lighter hydrocarbons. Natural gasoline plus recovery from stabilization, cracking and reforming provide the feed for the alkylation process, one source of 100-octane aviation blending agent.



Notes on the History of Synthetic Rubber

L. F. MAREK, Arthur D. Little, Inc.

WHEN war came to the United States on December 7, 1941, several types of artificial rubber-like materials, synthetic rubbers, already were being made commercially, among them some that had had several years of commercialization and others that had but a short life history but were destined to play important roles in the months to come. Thus may be mentioned:

Neoprene, made by E. I. du Pont de Nemours Company.
Thiokol, made by Dow Chemical Company for Thiokol Corporation.
Koroseal, made by The B. F. Goodrich Company.
Buna, made by Standard Oil Company (New Jersey) and two licensees, Firestone Tire & Rubber Company, and United States Rubber Company.
Ameripol, similar to buna and made by Hycar Chemical Company jointly owned by Phillips Petroleum Company and The B. F. Goodrich Company.
Chemigum, similar to buna and made by Goodyear Tire & Rubber Company.
Vistanex, made by the Standard Oil Company (New Jersey).
Butyl, not yet in commercial production, but for which plants are under construction by subsidiaries of Standard Oil Company (New Jersey).

At the present time, over eight months after that fateful December day, with our natural rubber supply cut off, our reserve supply dwindling at a rapid rate, and our military demands rising to ever-increasing totals, and with apparently new proposals and schemes for synthetic rubber or substitute rubber coming from all sides, it seems propitious at this time to give a quick glance to the history of "synthetic rubber" and particularly that of some of the most useful types. It will be reassuring to note from this survey that synthetic rubber is no new thing, that technicians have struggled for years to adapt the synthetic material to tire construction, and it will be easier to appreciate how the present tremendous synthetic program could be undertaken.

In his book, "Synthetic Rubber" published in 1926 by Ernest Benn, Ltd., London, Dr. S. P. Schotz makes an astonishingly prophetic statement. In the preface to the book, after discussing the limitations of natural rubber production, he says: "Synthetic rubber will therefore inevitably become one of the most important branches of industrial organic chemistry."

Today, this condition is on the brink of realization in the United States. Indeed, with the production of 870,000 tons per year of synthetic rubber in accord with the present program of Rubber Reserve Company, this synthetic organic product will be exceeded in tonnage by such basic inorganic chemicals as sulfuric acid, caustic soda, soda ash, but will not even be approached in value by any other chemical product. At 20 cents per pound the value of this annual production will approximate $350,000,000.

Early History

Synthetic rubber made from butadiene or isoprene has a history stretching back for over four decades, and while this may seem like a long time, the reader has only to recall that synthetic rubber, however poor it may have been, was being made commercially in continental Europe at the time of the World War (1914-1918).

The very early development of synthetic rubber, in several forms, was based largely upon the use of ethyl or butyl alcohols, obtained by fermentation, as raw material sources. Somewhat later acetylene derived from electro-chemically produced calcium carbide became the basis of some synthetic rubbers. Now, in order to meet the tremendous raw-material requirements for the domestic synthetic-rubber program, major dependence has been put on the petroleum industry to furnish the hydrocarbons required for the bulk of the program.

An entirely new, gigantic, chemical industry is being created with such rapidity that years of time are being compressed into months. Intense research work on the part of chemical, rubber, and petroleum companies has given rise to prodigious results. Improvements occur at such a rate as to almost overlap. Naturally, such a program involving many companies in several industries and telescoped in time would be accompanied by confusion and delays; but it is of great encouragement to see the ingenuity and flexibility that have been shown by industrial chemistry in meeting the emergency, and to realize that tangible progress is being made.

Several important dates and many distinguished names occur in the family history of synthetic rubber. Faraday, in England, had assigned the formula $C_{10}H_{16}$ to rubber in 1826. Himley, in a thesis at Göttingen in 1835, reported the isolation of certain products from the thermal decomposition of rubber, among them a low-boiling liquid which he called "faradayin." This was later identified as isoprene. Greville Williams, working in England at about 1860, reported the correct formula for isoprene, identified the formula with that for rubber, and observed that the liquid became viscous on standing, but solid-

ified violently when heated in a retort after having been exposed to oxidation for a short time.

Then G. Bouchardat, publishing in the French technical journals in the interval 1875 to 1880, showed that isoprene derived from rubber could be changed into a viscous elastic mass by heating in sealed tubes with all air excluded. Bouchardat further identified this isoprene polymer with rubber by means of a comparison of the properties of the two substances.

However, all of this pioneering work could not furnish a basis for synthetic rubber and it was not until 1884, when Sir William A. Tilden observed that isoprene was among the products from the thermal decomposition of turpentine, that an independent source of isoprene could be provided. In 1892, Tilden reported that the isoprene from turpentine spontaneously polymerized to a rubbery substances when stored in glass and that this polymer united with sulphur in the same way as natural rubber to give a tough elastic compound.

In 1909, Strange and Graham, Ltd., started to work on synthetic rubber in England and a few years later entered into a cooperative agreement with W. H. Perkin, Jr., who was also working on the subject. In 1912, Synthetic Products Company was founded to exploit the discoveries that had been made. Among the group working on synthetic rubber the following names may be mentioned: H. J. W. Bliss, H. Davies, H. M. Elder, A. Fernbach, T. Kane, F. E. Matthews, W. H. Perkin, Jr., C. A. Pim, R. W. Pope, Sir William Ramsay, P. Schoen, E. H. Strange, C. Weizmann, and E. C. B. Wilbraham.

The method adopted by this British group consisted in first preparing butyl alcohol by fermentation by means of the Fernbach and Strange patented process. This alcohol was dehydrated by treatment at 300-400° C. over pumice saturated with phosphoric acid to give butene-2. This butene was chlorinated to the dichloride and the dichloride finally decomposed over a heated nichrome wire to form butadiene. The butadiene was purified to the requisite quality for polymerization to rubber by means of the formation and isolation of the intermediate SO_2 complex and subsequent decomposition of the complex.

The patent application for the use of metallic sodium for the polymerization of isoprene and other conjugated diolefins to rubber of Matthews and Strange made in England was in patent interference both in England and Germany with a very similar application for the same invention of C. D. Harries and F. Bayer & Company. The Matthews-Strange application prevailed in both countries. The almost identical claims made by these two groups, even to the use of various amalgams as catalysts is an example of the remarkable parallelism that sometimes occurs in important developments between totally independent groups.

Synthetic rubber was intended to be only a side line in the workings of Synthetic Products Company, butyl alcohol and acetone being the primary products. In 1913-1914 the plant is reported to have had a capacity for making 15 tons of butyl alcohol per week and experimental lots of 2 to 3 pounds of rubber per day. The prevailing low price of natural rubber at that time destroyed all commercial prospects for the synthetic product.

Developments in Germany were also being pushed hard. It is interesting to note that Kondakow had reported the preparation of dimethyl butadiene rubber as early as 1900. Polymerization had been accomplished by prolonged storage of the hydrocarbon liquid in a closed container. By thus departing from the classical efforts of his predecessors, Kondakow[1] laid the foundations for Germany's wartime synthetic, "methyl rubber." It is reported that F. Hofmann manufactured a rubbery polymer at Leverkusen in 1910 by prolonged heat treatment of isoprene. F. Bayer & Company had a large, well-equipped laboratory from which a string of patents began issuing about 1910-1911 on synthetic rubber and raw materials. Reference has already been made to Harries' invention of the use of sodium metal as a polymerization catalyst. The Germans also turned to butadiene and more especially to dimethyl butadiene which was derived from acetone as their starting point. The acetone was obtained either from fermentation of potatoes or from calcium carbide - derived acetylene. Among the men working on this problem in Germany were Kondakow, Staudinger, C. O. Weber, F. Hofmann, C. D. Harries, Webel, Graul, Hanschke, Gottlob, and others.

The methyl-rubber produced from this dimethyl-butadiene suffered from many drawbacks, particularly with respect to vulcanization. Furthermore, the material was more like leather than rubber. Nevertheless, the experience of the Bayer Laboratories were of great value to Germany during the operation of the British blockade during the 1914-1918 World War.

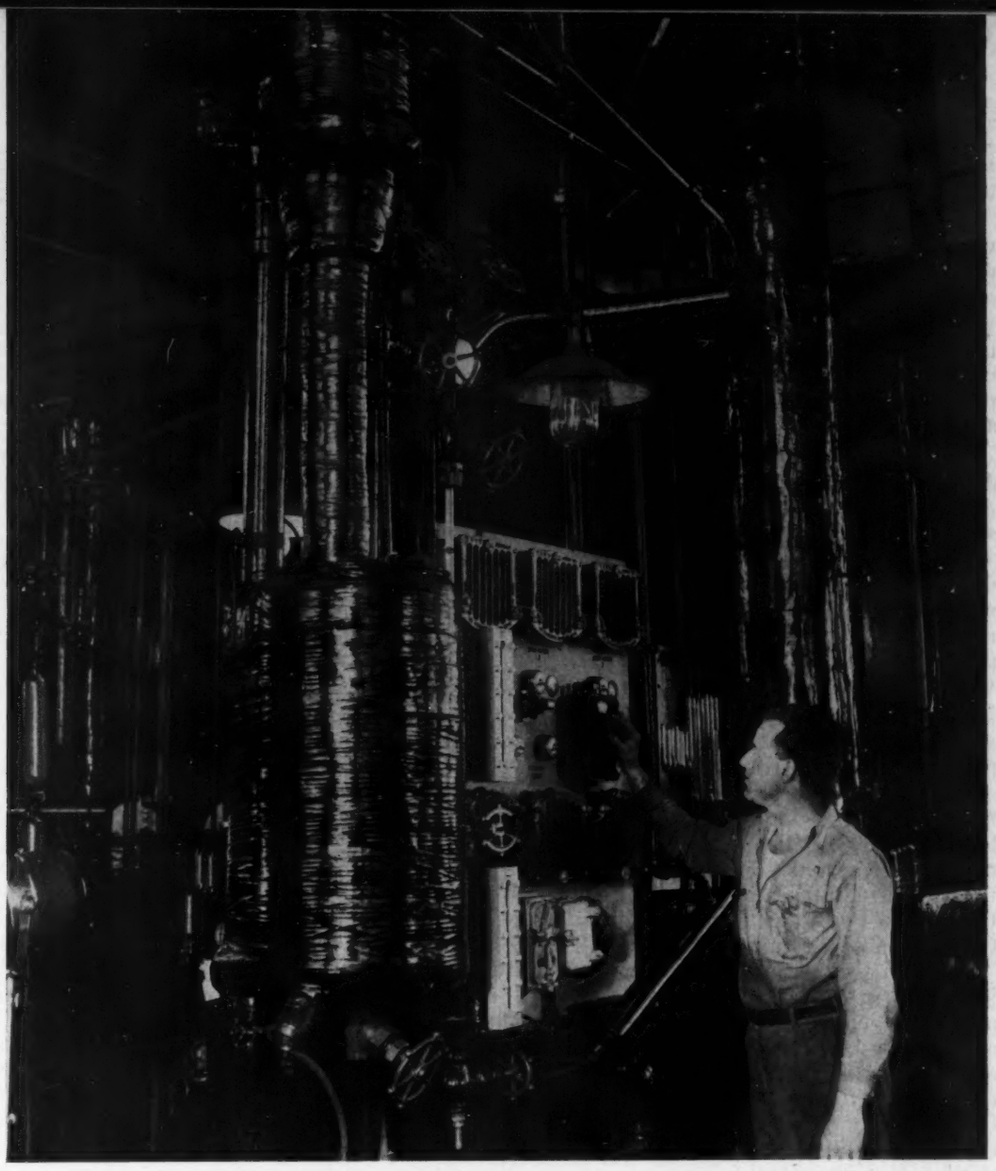
In 1912, Dr. Duisberg of the Badische Aniline u. Soda Fabrik (F. Bayer & Company) exhibited at the International Congress of Applied Chemistry in New York a pair of automobile tires made of synthetic rubber. At the time, this was looked upon as a fine bit of showmanship. The German government had subsidized the research and development in this field, primarily as a matter of military necessity. Rapid advances were also being made in Germany at this time in the development of synthetic ammonia and synthetic methanol as the direct result of the application of tremendous research activity. Looked at in retrospect, it is easily seen that this activity was directed to making Germany independent of imports of these basic materials in preparation for the war that was to come.

During the war interval 1914-1918 Germany is reported to have produced only about 2300 tons of synthetic rubber — methyl rubber made from dimethyl butadiene derived from acetone.[2]

A detailed account of the experiences of the Germans with this synthetic rubber has been given by Gottlob and summarized by Whitby and Katz.[3]

Three techniques of polymerization were used to give products specifically adapted for certain uses. Thus, mark H rubber made by polymerization at room temperature for 3 or 4 months was used for storage-battery boxes to the extent of about 30 tons per month and for tires to the extent of about 10 tons per month by the spring of 1918. Mark W rubber made by polymerization at about 160° F. (70° C.) for several days was used for rubber-asbestos packings, insulated wire, balloon fabric, etc. Mark B rubber was made by the Badische at Ludwigshafen by metallic sodium-catalyzed polymerization in an atmosphere of CO_2. This material had better working quality than did Mark H rubber, and hence was superior for uses such as wire insulation which requires extrusion.

The tremendous importance of carbon black as a



PILOT PLANT

compounding ingredient for these synthetic rubbers was not recognized at the time of the war or the value of synthetic rubber to Germany would probably have been far greater than it was. The post-war patent literature emanating from Germany stressed this importance of carbon black as a compounding ingredient, showing that the effect had later been recognized.

Russian scientists also were actively engaged on a study of synthetic rubber raw materials and manufacture. The Russians also turned to butadiene as a likely raw material. Ostromisslensky, Ipatief, Andreeff, Lebedef were all working in the field.

In 1910, Lebedef reported that he had obtained a polymer having rubber-like properties by heating butadiene. No significant developments apparently occurred, however, and no enthusiastic reports of the properties of such polymers were made.

Intermediate Period

After the war, this active interest in synthetic rubber lapsed for a period of almost a decade, presumably due to the low post-war price of natural rubber. A low of about 14 cents a pound was reached in 1922. Then with the working of the Stevenson monopoly plan for price control of natural rubber and the accompanying rise in price to about $1.00 by the end of 1925, interest was renewed in Britain, the United States, and Germany. From 1926 on and especially after 1929 the I. G. Farbenindustrie in Germany began to take out large numbers of patents. In Russia, experimental work was apparently continued also on the basis of military necessity.

However, with a drop in production costs of natural rubber from about 24 cents per round in 1912 to about 7 to 9 cents in 1929 and the intervening breakdown of the Stevenson price-control plan, synthetic rubber held out promise only as a specialty product to meet unusual industrial use requirements in Britain and the United States. In the United States, research was continued under the driving force of private capital by companies in the chemical manufacturing, rubber, and petroleum industries, and was directed specifically at the formation of materials with properties superior to natural rubber for specific uses, especially where resistance to solvents and oils was important.

Modern Developments

The modern history of synthetic rubber in Germany is intimately linked with the ambitious undertakings of the I. G. Farbenindustrie to dominate the European chemical industry and to penetrate deeply into world chemical markets, with the rise to power of Hitler, and with the pressure of nationalism. Hitler organized his Munich putsch in 1923, wrote "Mein Kampf" in 1925, and together with the financial and political help of industry rose to full power in 1933. At about this time Germany's plans for industrial self-sufficiency received additional impetus and too

by this time I. G. had achieved far-reaching penetration into world chemical industry.

Efforts to produce synthetic rubber in Germany were continued in an effort to reduce imports of raw materials as well as to develop special-purpose synthetic rubbers and in 1934 the "Buna" rubbers were developed from butadiene as a base. Production began in 1935 by a subsidiary of I. G. Farbenindustrie at Schokopau in Central Germany under a protective government tax on crude-rubber imports and with the aid of rubber-goods manufacturers.

Apparently the German government had come to dominate the work of I. G. Farbenindustrie by 1935. As late as 1936 or 1937 the Germans were not too successful with the development of the Buna rubber since they were interested in arranging a license from du Pont for neoprene manufacture. This license was never arranged and from about this time rapid progress was made in Germany with the butadiene copolymer types of Buna.

The three grades of Buna first produced by the sodium metal catalyzed polymerization of butadiene, namely, Bunas 32, 85, and 115 were inferior to the products derived from the special copolymerization of butadiene with styrene, Buna S and with acrylic nitrile, Buna N and NN, and have subsequently been abandoned. The acrylic nitrile copolymer materials were the only ones exported from Germany to the United States and were marketed here as Perbunan and Perbunan Extra by Advance Solvents and Chemical Corporation.

German production of butadiene was from acetylene, and in 1934 the American consul at Frankfort am Main reported the existence of two plants, one at Huls to use electric arc cracking of residues from synthetic gasoline plants to produce acetylene, and one at Schokopau to use acetylene derived from carbide. At that time, it was reported that Buna S[4] had been found superior to natural rubber for treads on the basis of its superior wear resistance. Apparently, many of the problems regarding the processing and use of Buna rubber had been overcome since it was expected that the previously used 30 percent of natural rubber could be dispensed with in tire production without the predicted greatly enlarged processing equipment. The anticipated erection of a Buna rubber plant near Bruex in the heart of the soft-coal-mining region of the Sudeten indicates the extent to which synthetic rubber was being expanded.[5]

In Russia, the first tires with 100 percent sodium butadiene rubber,[6] SK rubber, treads and sidewalls were made in December, 1932, at the Krasnaya Treugolnik and soon rubber factories at Leningrad and Jaroslaw were working on similar lines. In July, 1933, 18 automobiles fitted with tires of natural rubber, tan sagyz rubber, and SK rubber were sent on a round trip from Moscow to Kara-Kum, Turkestan. Considerable trouble was experienced from tread separation in the tires made with SK rubber, but the differences in behavior of similarly made tires from different factories showed the importance of skill and experience in working with the synthetic rubber. Many of the tires made with SK rubber completed the entire mileage and some 100 percent-SK-treaded tires gave almost as good mileage as those made from natural rubber, in fact 100 percent SK treads showed only about 70 percent the weight loss from abrasion that natural rubber treads showed.

In July, 1936, a similar test was made with 15 automobiles in the fleet. The results showed considerable improvement but indicated that the major problem was still lack of proper adhesion of tread to carcass of the tire. In 1939, tests showed that progress had been made toward solution of the problems but that they were not completely solved; and in 1940 the proportion of natural rubber to synthetic had been further reduced.

The third 5-year Russian plan (1937-1942) called for increase to 95 percent of SK rubber plus 5 percent natural rubber in SK tires. The Truman committee of the United States Senate estimated that Russian production of synthetic rubber was approximately 50,000 tons annually. This production[7] was believed to be of the Buna type made from agricultural alcohol.

Russia has also produced Sovprene, the Russian variety of neoprene, and research has been expended in an effort to adapt this material for use in inner tubes and possibly with SK rubber in tires. It is not known how much Sovprene is being produced.

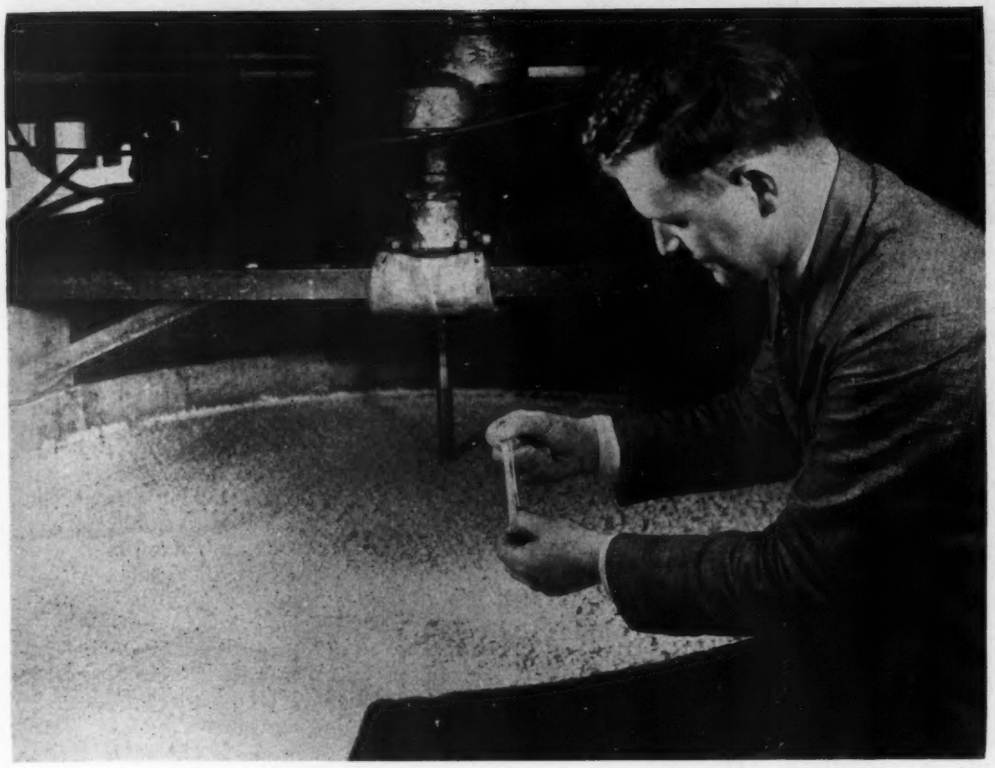
In the United States synthetic rubber had been developed for special-purpose uses, the synthetics being unable to compete with natural rubber from the Far East in normal circumstances. Production of these synthetics, especially the oil-resistant forms, grew from about 2500 tons in 1939, to 4500 tons in 1940, to 9000 tons in 1941. By the end of 1941 production capacity was about 20,000 tons annually. Among these specialty synthetics were: Neoprene made by E. I. du Pont de Nemours & Company, Thiokol made by Dow Chemical Company for Thiokol Corporation, Koroseal made by The B. F. Goodrich Company, and Vistanex made by Standard Oil Company (New Jersey). The B. F. Goodrich Company had brought into small commercial production a general purpose synthetic, Ameripol, in 1940, and in the summer of 1940 had offered for sale tires made from this material.

Goodyear Tire & Rubber Company had operated a semi-commercial plant for the production of an oil-resistant synthetic called Chemigum and had built and tested tires made entirely of the synthetic. Other American developments in the field of general synthetics had been undertaken but were deterred from commercial exploitation on the basis of the economics.

Buna-N or Perbunan as it was known was imported to this country to supply the specialty uses filled by neoprene at the time neoprene production was interrupted by the plant explosion of 1938.

On the basis of agreements made in 1929 with I. G. Farbenindustrie Standard Oil Company (New Jersey) received information regarding the developments in the buna-type of synthetic rubbers in Germany; and in 1939 acquired title to about 2000 patents, including those on the Buna rubbers. In the early part of 1940[8] it offered licenses for manufacture of rubber under these patents; but by late 1940 it was indicated that the government would proceed with plans for synthetic-rubber production. In June, 1940, Standard Oil Company (New Jersey) worked out cooperative arrangements with Firestone Tire & Rubber Company and United States Rubber Company.

During the time that licenses were being offered to American rubber companies, Standard Oil Company (New Jersey) proceeded with the construction of a small plant for production of Buna N, the butadiene-acrylic nitrile copolymer, having a capacity of five tons per day (1650 tons annually). This plant



Rubber content is solidified by coagulation in dilute acids. Here Dr. Waldo L. Semon, tests elasticity of the product.

Courtesy, The B. F. Goodrich Company

was completed in April, 1941, and was subsequently doubled in capacity. This plant was used also to produce a quantity of Buna S, the butadiene-styrene copolymer, for use in experimental tire construction.[9]

Some of the American rubber companies had been conducting research directed to the production of specialty synthetic rubbers, and had advanced beyond the pilot-plant stage in the production of butadiene-based synthetics. Goodyear Tire & Rubber Company had developed Chemigum and The B. F. Goodrich Company had produced Ameripol; and both companies had built and tested tires made from the synthetic prior to 1941.[10] The latter company also entered into a joint enterprise with Phillips Petroleum Company and formed Hycar Chemical Company to produce the oil-resisting-synthetic Hycar.

On May 15, 1941, Defense Plant Corporation entered into contracts with four major rubber companies, Goodyear, Goodrich (Hycar Chemical Company), Firestone, and U. S. Rubber, for construction and equipment of synthetic-rubber plants which would each have an initial production capacity of only 2500 tons annually but which could be readily expanded to 10,000 tons annual capacity. And then on July 1, 1941, these four authorized plants were increased to the 10,000-ton annual capacity. Actually, these plants were expected to have capacities of 15,000 tons annually each.

Construction of these plants started as follows: Goodyear in May, 1941; Firestone in July, 1941; U. S. Rubber in September, 1941; and Hycar in February, 1942. Contracts for the production of raw materials for this limited program were authorized in November, 1941. These plants have come into production or are expected to come into production about as follows: Goodyear in May, 1942; Firestone in June, 1942; U. S. Rubber in August, 1942; and Hycar (Goodrich) in November, 1942.

On December 19, 1941, the four rubber companies and Standard Oil Company (New Jersey) set up a "pooling agreement" for the exchange of information and cross license under their patents on butadiene rubbers. On March 10, 1942, the oil company announced that Butyl rubber licenses would be given royalty-free for the war duration and for government-fixed reasonable royalties for post-war production. Then on March 25, 1942, it signed an equity decree in an anti-trust proceeding-consent decree—which changed some of the foregoing agreements. Thus, Standard Oil Company (New Jersey) agreed that it would charge no royalty on Buna patents for the period of the war and that it would license the patents to anyone after the war for reasonable royalty rates; that it would license royalty-free only such Butyl rubber inventions as had already been actually patented before the date of the decree for the war period and was obligated to grant Butyl licenses after the war on patents issued before the end of the war or based on applications filed prior to the consent decree.[11]

Since Pearl Harbor the government's program has been repeatedly expanded as the foreseen emergency became an actuality. These first four plants were first expanded to a total of 120,000 tons per year capacity. Then additional facilities were provided to make a total of, first, 400,000 tons per year, later of 600,000 tons, and still later 800,000 tons including 60,000 tons butyl rubber and 40,000 tons of neoprene.

The execution of this tremendous program has naturally brought with it numerous problems especially those concerned with the production of the necessary butadiene and styrene. The other responsibilities of the petroleum industry in the war effort, especially in regard to production of aviation fuel and lubricants and of toluene have had to be considered in relation to this rubber program.

These aspects of the program have been con-

sidered in other papers of this series and need not be discussed here.

The individual histories of some of the special purpose synthetics, manufacture of which continues during the emergency, are given to show the extent of the modern American developments in the field.

Neoprene

As early as 1925 du Pont chemists had undertaken the development of a new rubber-like material which would be better adapted to the new industrial requirements than natural rubber. In 1927, means had been worked out for the conversion of acetylene to divinylacetylene. However, attempts to convert this material to a synthetic rubber failed. Later it was found that acetylene could be dimerized to vinylacetylene and that this substance could be converted into substituted butadienes by additions at the acetylenic bond. Development from this point was rapid.

Then two papers from the laboratories of the E. I. du Pont de Nemours Company appearing in the November, 1931, issue of the Journal of the American Chemical Society served to announce that American research had led to the initial development of a new type of synthetic rubber. One of these, by Nieuwland, Calcott, Carter and Downing described the development of means for the polymerization of acetylene to vinylacetylenes based on the earlier academic work of Nieuwland. The other by Carothers, Williams, Collins, and Kirby described the formation of chloroprene from vinylacetylene by addition of HCl and its polymerization to a plastic, rubber-like material.

On the basis of this work, du Pont in 1931 entered into the commercial production of polychloroprene rubber, first termed "Du Prene" and later in 1936 designated neoprene. Depending upon polymerization conditions the polymer produced could be made to vary from a terpene-like oily dimer to a hard, granular, non-elastic substance with products resembling milled rubber or vulcanized rubber in between.

By 1935, neoprene was being made in a plant capable of producing at a rate of over 500 tons per year. This plant, subsequently enlarged to a capacity of about 1500 tons per year was destroyed by an explosion in early 1938. A new plant with a reported capacity of 2000 to 2500 tons per year was in operation before the end of that same year. By 1939, this plant had again been enlarged, with the du Pont objective for neoprene given as about 1 percent of natural rubber or about 7000 tons per year.

Imperial Chemical Industries, Ltd., in England has been licensed to manufacture neoprene. Neoprene-type rubber, Sovprene, has been made in Russia in a plant at Erivan, construction of which began in 1933. It is reported that negotiations between du Pont and the German I. G. Farbenindustrie for license on neoprene manufacture in Germany failed in 1936 or 1937 and that similar negotiations with Japanese interests failed to be made in 1938.

The present government program calls for capacity to produce 40,000 tons annually of neoprene under du Pont direction. The expected time schedule has been estimated to be about as follows:[12]

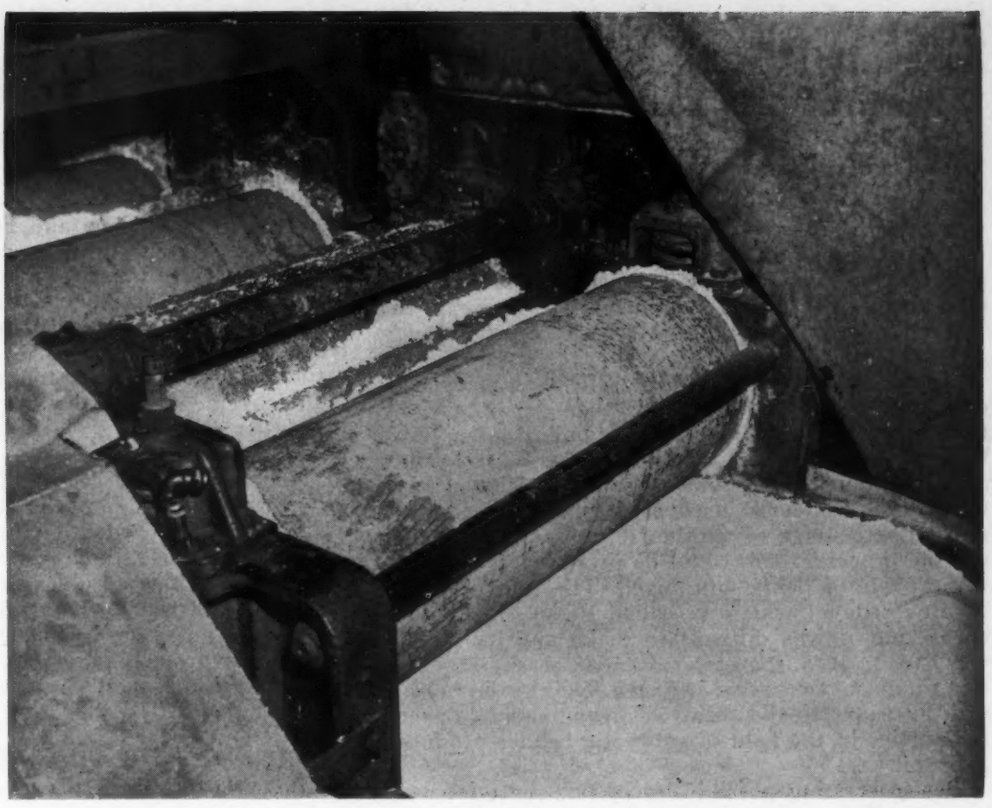
first half 1942 actual = 3600 tons
second half 1942 objective = 8400 tons
total 1942 = 12,000 tons
total 1943 objectives = 21,000 tons.

The du Pont plant capacity is about equally divided between Deepwater Point, New Jersey, including privately financed capacity, and Louisville, Kentucky.

The adaptation of neoprene to tire construction

Buna rubber after milling is cut into ribbons, then into sheets.

Courtesy, Standard Oil Company of New Jersey



Water and other surplus materials are removed from products of weigh and reactor tanks by rolling.

Courtesy, Goodyear Tire and Rubber Company

had been considered as early as 1934 in cooperative experiments between du Pont and the Army.

Thiokol

Thiokol[13] was produced accidentally in the early 1920's by Dr. J. C. Patrick while attempting to produce a cheap anti-freeze from ethylene dichloride and sodium polysulfide. Patrick observed the rubber-like properties of the reaction product he obtained and applied for patents in 1928.

Since that discovery, it has been found that many other organic dichlorides could be condensed with sodium polysulfide to give rubbery materials. For instance, the use of dichlorodiethyl ether instead of ethylene dichloride gives a more rubber-like material than the original Thiokol.[14]

The discovery was capitalized through the formation of Thiokol Corporation which, according to recent advertisements, began commercial operations in the latter part of 1929. Thiokol Corporation continued to produce the material until 1938 when manufacture was taken over by Dow Chemical Company, presumably on a contract basis since Thiokol Corporation continues as sales agents and in development work.

Thiokols may be compounded with many of the compounding ingredients in common use with rubber, and results comparable to those obtained with rubber for many purposes are obtained. For instance, Thiokol prepared to be plastic, mixed with zinc oxide, and heated, undergoes a change comparable to vulcanization yielding a non-plastic, elastic product. Carbon black greatly stiffens Thiokol, so that the range of properties obtainable in the final product may be varied as with rubber.

Thiokol has found certain use applications on the basis of its extremely good resistance to a large number of organic solvents and relatively slight swelling in them. The usual varieties of Thiokol (there are several) have excellent resistance to natural aging, weathering, sunlight, ozone, and ordinary temperatures. However, the material that has been widely used for wire and cable insulation, gasoline-hose lining, printing rollers and blankets, etc., had never been considered as a possible tire tread stock to replace natural or reclaimed rubber; but now tire-Thiokol is being actively promoted.

On the basis of representations by Dr. Willard Dow of Dow Chemical Company that it could make a Thiokol-rubber suitable for recapping tires and capable of giving 5,000 to 10,000 miles of service when driven at not over 30 miles per hour, the War Production Board on June 16, 1942, issued a letter of intent to the company to cover facilities for increased production of Thiokol-rubber sufficient to provide material for 500,000 tire recaps per year. No definite statements have been issued regarding the nature of this tire-Thiokol or the raw materials to be used. That it will be different from current Thiokol types may be inferred from statements regarding the pilot-plant operations needed before large-scale plant design was possible.

Present Thiokol capacity has been given as 15,000 tons per year by the fall of 1942. The objective for the expansion on the basis of this tire-Thiokol has been given as 60,000 tons per year. Recently, Thiokol Corporation began manufacturing again, this time for the production of special Thiokol latex for use in war equipment.

It has been reported (August) that du Pont may enter the tire-Thiokol-producing picture on the basis of having idle equipment suitable for the manufacture together with necessary raw materials.

Material similar to Thiokol has been produced in

Germany under the name of Perduren and probably has been used wherever possible to displace natural rubber. Russia also is reported to have constructed a plant for production of Thiokol-type rubber in 1934. Monsanto Chemical Works, Ltd., British subsidiary of Monsanto Chemical Company, was licensed to produce Thiokol for the European market.

Butyl Rubber

To quote from the statement of W. S. Farish, president of Standard Oil Company (New Jersey), made before the Senate committee to investigate the National Defense Program, March 31, April 1 and 2, 1942:

"Butyl rubber was the outgrowth of research conducted first cooperatively and then separately, by the German I. G. Company and Standard in an effort to find a way to vulcanize a rubber-like product called Vistanex which had originated with the I. G. Company. Standard discovered that by adding a minute percentage of another ingredient and changing the process, there could be produced a true rubber capable of being vulcanized. The raw materials for this product which we called Butyl rubber were cheap, but it was difficult to make and its quality was bad. In 1938, soon after Standard had discovered this product, it reported it to the I. G. in the normal way pursuant to the research arrangement between the parties in the field of synthetic rubber produced from oil."

The interesting possibilities of this material were immediately recognized and further research was devoted to it in order to improve the properties. Some of the properties of butyl, as then made, were described in an article[15] published in 1940. These properties may be enumerated as follows:

- extremely resistant to chemical attack;
- non-thermoplastic after vulcanization;
- not resistant to aliphatic hydrocarbons, but having surprising resistance to benzene, ethylene dichloride, oxygenated solvents;
- exceptional flexing resistance;
- better age resistance to temperature, light, and ozone than natural rubber;
- higher carbon-black (Gastex) loadings than natural rubber;
- less increase in tensile by carbon black than natural rubber;
- rebound much less than rubber at room temperatures;
- abrasion resistance of stock carrying heavy carbon black loading better than rubber with usual loading.

Standard states that all exchange of information on Butyl rubber with the Germans was stopped in January, 1940, and in the meantime it had explored the problems of production in laboratory pilot-plant units of maximum capacity of half a ton per week. By March 14, 1941, Standard engineers were ready to design a commercial unit. On June 11, 1941, the company appropriated $2,500,000 for such a plant and on October 27, 1941, appropriated an additional $2,000,000. Thus, before the end of 1941 Standard had under construction a Butyl rubber plant, using its own money, with a projected capacity of 7300 tons per year and estimated to cost $4,500,000.[16]

From June, 1940, on, in cooperation with rubber companies and others, tests were made on the use of Butyl rubber for construction of automobile tires. The first tires were very bad, but by the early part of 1942 sufficient improvement had been made to warrant the statement that itres of Butyl rubber could be built to last for 10,000 miles when driven at moderate speeds of 35 miles per hour.[17]

At the end of May, 1942, the government's synthetic-rubber program called for construction of two Butyl-rubber plants with an aggregate capacity of 60,000 tons per year, to be operated by Standard Oil Company of Louisiana and Humble Oil & Refining Company. At that time, it was planned that Butyl would be used primarily for inner tubes for which it was believed satisfactory. Costs were estimated to be 18½ to 19 cents a pound, including the management fee and all capital charges.[18] Original plant cost was estimated to be $700 per ton annual capacity.

Improvements have been made to an extent that plant-cost estimates have been reduced to $350 per ton annual capacity. Butyl costs have been stated to start at about 20 cents a pound, but to possibly drop to somewhere between 10 and 15 cents a pound with large-scale production.[19]

By August, 1942, the improved technique for Butyl production made possible an increase in expected capacity of 70,000 tons per year, bringing the total Butyl capacity figure to 130,000 tons per year.[20] This increase in projected capacity was not expected to affect the contemplated production of 300 tons of Butyl in 1942.

Plasticized Polyvinyl Chloride

Koroseal, the result of research and development by The B. F. Goodrich Company, is a synthetic, elastic material made by the plasticization of polyvinyl-chloride. Variations in properties from a soft gel to a rigid, hard material may be obtained. The substance is a true thermoplastic and is not capable of vulcanization. Tensile strengths vary with hardness from about 1000 to about 8000 pounds per square inch.

Uses for the material are many, including coatings for various materials ranging from metals to textiles, special hose and tubing fabrication, insulation of wires and cables, packaging materials, sealing compounds, etc. One of its most useful properties is chemical inertness.[21]

Similar materials are the Flamenols of General Electric Company, and the product of Maurice A. Knight Company. In Germany, I. G. Farbenindustrie has produced Mypolam, Mowilith, and Igelite.

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Chemistry of Synthetic Rubber

DURING recent months there have been literally hundreds of different articles published on synthetic rubber. These have included excellent technical presentations, reports of public hearings, publicity releases, and opinions. They have been prepared by well-informed technical men of the synthetic-rubber industry, by informed chemists, by engineers who may or may not be familiar with the materials themselves, by interested laymen, by publicity counsel, by newspapermen, and by individuals who merely felt the urge to express themselves.

Naturally, the opinions, and often statements that were made as fact, have not been uniform, so it is again natural that a great deal of confusion exists as to the true character of synthetic rubber.

THIS article was prepared in the Rubber Chemicals Division of E. I. du Pont de Nemours & Company, where, to quote from a letter of transmissal:

"It is recognized that there are several practical methods by which each of the chemicals and each of the synthetic rubbers can be made. Quite probably many of these methods will be obsoleted within a few months by technological advancements, consequently detailed descriptions of manufacturing methods at this time would be futile if not erroneous."

This attitude is typical of the attitude toward rubber-like products from chemical processing in all scientific circles. These changes are the assurance of progress.

Not a New Development

One of the major misunderstandings is the widespread belief that synthetic rubber is a very recent development. This is completely erroneous. All of the general types of synthetic rubber currently being manufactured in this country, with the exception of the butyl types, have been in regular production in some parts of the world for a good many years. Even the exception, butyl rubber, is merely the advanced application, albeit, an important one, of a material made and used for several years. In the case of the other synthetic rubbers, the materials produced today are not exactly the same as those produced a few years ago, but the differences are in the line of process improvement or improved interpolymers rather than a radical change in basic structure.

Engineers in the oil industry probably do not have this misconception of the facts, although such thinking is general throughout the country. The oil industry has known, used and valued synthetic rubber for over ten years, during which time thousands of oil-industry products made from neoprene and Thiokol have proved their worth under severe service conditions. In addition, products made from imported buna-type rubbers were utilized three and four years ago, while products made from oil-resisting buna rubbers made in the United States have been in regular service for over two years.

The one point that is not generally understood is that the types of synthetics which have already proved their worth have been steadily improved by their producers, while research on compounding has tended to improve vulcanizates made from these synthetics to an even greater extent. Illustrating this point, there are today several different types of Thiokol and a number of new types of neoprene—types which do not swell appreciably when immersed in oil, and, most important, maintain their physical properties virtually unchanged after such exposure; types which have no odor, which will resist the effects of extremely low temperatures, etc.

There Is a Difference

Another general misconception is that the synthetics are duplicates of the natural product. None of the five major types of synthetics is a duplicate of natural rubber either in chemical composition or in method of use. Four of these types have chemical structures that are similar to the structure of the natural product, but there are important differences. There are also important differences between the five major types, both in chemical composition and in their properties. Three are oil resisting, four are abrasion resisting, two are truly heat resisting, two are sunlight resisting, etc.

Three of the five types of synthetic rubber were developed to fill the need for a rubber-like product that would resist the effects of deteriorating influences—they are not rubber substitutes, but, rather, superior materials for difficult jobs.

Immediate Use Difficult

Contrary to general opinion, all of the synthetic rubbers can not be used to the fullest extent of their capabilities as soon as they are manufactured in quantity. A great deal of compounding research is necessary before the rubber chemist can obtain the best results. This research is, of course, going forward rapidly, but it will take time to determine the best compounding procedure. Excellent compounds have already been developed using the older synthetics, and this development will be of considerable assistance in future work.

In addition, engineers will frequently have to re-

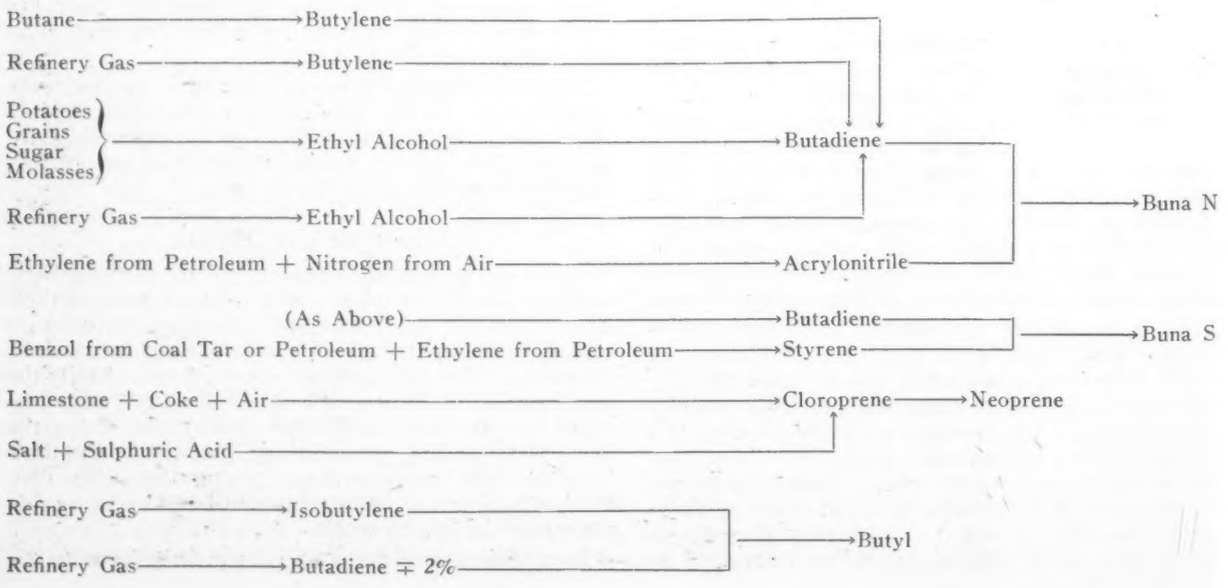
vise their opinions on the way to use synthetic rubbers. Each new product must be considered separately. Further, as the art of compounding is advanced, products made from these compounds will do a better job than previous compounds in the same way products made from today's Thiokol and neoprene formulations do a better job than similar products did just a few years ago. Some of the newer types of synthetic rubber may actually shrink when exposed to oils. This is a disadvantage when they are used as a gasket, so a minimum swell must be specified. Volume increase is not, however, the true index of oil resistance. The most important factor to consider is the percentage of the original tensile strength maintained by the oil-swollen product.

Every product which can be made from natural rubber can be made successfully from one or more of the synthetics. Perhaps the cost will be higher, and perhaps the physical properties of the synthetic vulcanizate will be slightly different from those possessed by the natural rubber product, but the article will be eminently satisfactory, often superior to the previously-used article. Of importance to the engineer considering the long-term picture is the fact that in the present stage of compounding research some synthetics require the use of natural or reclaimed rubber in the compound to produce certain types of products. For oil-resisting applications with the older synthetics this is not true; nor is it true with all synthetics. However, the fact is of importance, as the properties of the vulcanizate will change as it becomes increasingly necessary to reduce the rubber-synthetic ratio in order to conserve our dwindling supplies of crude and reclaimed rubber, and as compounding research perfects methods for eliminating the natural or reclaimed rubber from the compound. It might be of interest to note at this point that excellent passenger-car and truck tires have been made from synthetic rubber. Experimental tires have been made successfully from United States synthetic rubbers for ten years; and are now being made in ever increasing quantities.

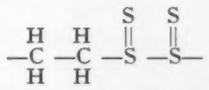
Chemical Composition and Manufacture

The synthetic rubber-like materials now being produced in the United States can be classified into five general groupings. In the order of the start of their manufacture in this country they are (1) polysulfide rubbers, known as "Thiokol"; (2) chloroprene rubbers, known as neoprene; (3) butadiene-vinyl cyanide interpolymers, Buna N, "Perbunan," "Chemigum," "Hycar"; (4) butadiene-styrene interpolymers, Buna S; (5) isobutylene interpolymers, butyl, "Flexon." These are the synthetic rubbers on which the country will depend for the great bulk of its resilient, elastic materials for the duration of the war. There are other materials manufactured in this country which can replace rubber in some applications, inasmuch as they have some rubber-like properties, but none of the other materials is as generally usable as the five types listed above. These other materials include (a) ethyl cellulose; (b) the plastic glyptal resins, condensation products of a polybasic acid, such as phtalic or adipic, with a polyhydric alcohol, such as glycerin or ethylene glycol; (c) polyvinyl alcohol; (d) plasticized polyvinyl resins such as are sold under the trade names "Koroseal" and "Vinylite"; (e) polysobutylene, known as Vistanex, the forerunner of the isobutylene interpolymers listed under (5) above; (f) polyvinylidene chloride, "Saran"; (g) polyvinyl acetals, "Formvar," "Butvar," "Vinylite X," "Butacite"; (h) plasticized polyacrylic esters, "Acryloid"; and (i) mixed alkyd condensation products.

Any statement which presumes to give details as to the way the five major types of synthetic rubber are manufactured would require a volume to present and would quite probably be almost wholly inaccurate. Details have never been revealed on the methods used by four of the major manufacturers. In addition, there are many successful manufacturing methods now being used to produce some of the types (the recent report of the Baruch committee recognized several of these methods), and scientific research is changing manufacturing procedure almost every day. For these reasons, the following description of the nature of the synthetics and the way they are produced will avoid the folly of meaningless details by presenting the information only in a general manner. A simplified chart released by the War Production Board is as follows:

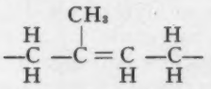


(1) *Polysulfide Rubbers.* These products have been made commercially in the United States since 1930 by Thiokol Corporation, and later by Dow Chemical Company. They differ from the other synthetic rubbers in that they are made not by polymerization but by the condensation broadly of an organic dihalide with sodium polysulfide. The condensation is carried out in an aqueous medium with the chlorine of the dihalide and the sodium atom of the polysulfide combining to form salt, which is removed by washing. The chemical structure of one type of polysulfide rubber is as follows:

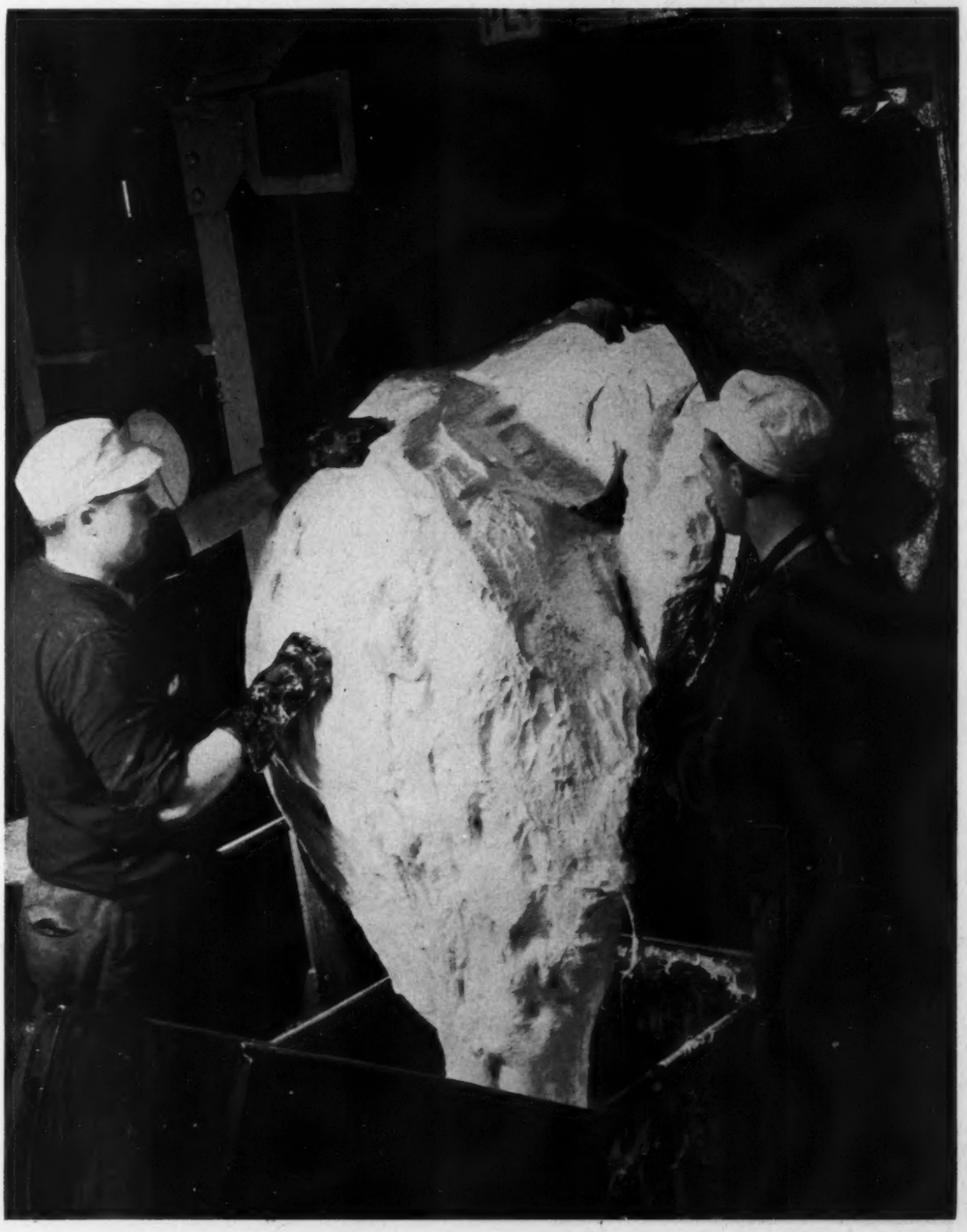


Presented simply, polysulfide rubbers are made from salt, sulphur and crude oil. Caustic soda and chlorine are made from the salt. From the sulphur and the caustic soda, sodium polysulfide is produced. The chlorine together with ethylene from crude oil is used to produce ethylene dichloride. Sodium polysulfide, ethylene dichloride and other hydrocarbon derivatives from crude oil are combined in a reactor to produce polysulfide latex. After this latex is purified polysulfide rubber in its crude form is the result.

Isoprene. Contrasting with the polysulfide rubbers, the other four types are all polymerization products and each of them has a chemical structure very similar to isoprene (natural rubber). This structure is



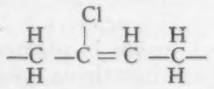
In one type of synthetic, the methyl group, CH_3, is replaced by a chlorine atom, Cl. In the other three types, this methyl group is replaced by a hydrogen molecule, H, to form butadiene, and then butadiene is polymerized in the presence of metallic sodium to produce the final product. In most cases, this altered



NEOPRENE

chemical structure is combined with another chemical structure to produce interpolymers.

(2) *Chloroprene Polymers.* This synthetic rubber, made by the polymerization of 2-chlorbutadiene, was invented in the laboratories of E. I. du Pont de Nemours & Company in the late 1920s and the first plant for its commercial production was started in 1931. Chlorbutadiene, more commonly known as chloroprene, is made by the addition of hydrogen chloride to monovinylacetylene under the influence of a catalyst. Monovinylacetylene is made by the condensation of two molecules of acetylene. Chloroprene is polymerized by emulsifying in water. The simplified chemical structure of chloroprene is



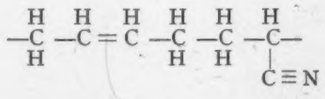
Chloroprene rubber starts from basic materials equally prosaic as those used to produce the polysulfide rubber—coal, limestone, salt and water. Coke is produced from the coal, and this coke is used with the limestone to produce calcium carbide. Acetylene gas is made by bringing water into contact with calcium carbide. (The widely publicized process for making acetylene from oil has not as yet been used commercially.) Hydrogen chloride is produced from the salt. The product may be stabilized as a latex or polymerization continued to produce a crude material very similar in appearance and feel to crude rubber.

(3) *Butadiene-Vinyl Cyanide Interpolymers.* This type of synthetic, known also as Buna N, made by the interpolymerization of butadiene and vinyl cyanide, was developed in one form by the German I. G. Farbenindustrie A. G. and was first announced in 1935. Sales were made in this country as early as 1938. The manufacture of Buna N type synthetics

PERBUNAN

CHEMIGUM

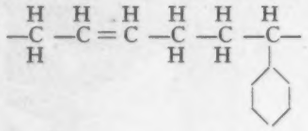
made by a number of different processes began in this country in 1940. Companies now manufacturing synthetic rubber of this general type include Standard Oil Company of New Jersey, Firestone Tire & Rubber Company, Hycar Chemical Company, and Goodyear Tire & Rubber Company. The various brands are not identical presumably differing in the ratio in which the two components are present and also in the nature of emulsifying agents, polymerization catalysts, etc. Details of the various manufacturing processes have never been revealed. The general chemical structure is



Inasmuch as the production of this type of synthetic follows much the same form as the more discussed Buna S (see 4), details will not be covered at this point. The major difference is in the use of vinyl cyanide, acrylonitrile, as the interpolymer. In one method, this chemical is produced from ethylene (made from salt and crude oil as noted previously) and nitrogen which is obtained from the air. Here again, scientific development is so rapid that it is impossible to give up to the minute details as to the manufacturing processes.

(4) *Butadiene-Styrene Interpolymers.* The interpolymerization of butadiene and styrene was also developed by the German I. G. and has been produced in Germany since 1935. The product is now being produced in this country by Firestone Tire & Rubber Company, B. F. Goodrich Company, Goodyear Tire & Rubber Company, and U. S. Rubber Company, for the account of Rubber Reserve Company. Polymerization is effected by emulsifying butadiene and styrene in water with soap or a synthetic emulsifying agent and holding the emulsion at

a slightly elevated temperature. A number of different companies are now, or soon will be producing butadiene, while styrene is to be made by several different chemical manufacturers. The chemical structure is

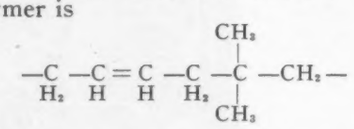


This butadiene-styrene synthetic rubber is the type which makes up the biggest proportion of the government's synthetic program. This decision was based on the amount of critical materials required for the production, the power requirements, the availability of raw material, the speed with which the plants could be built and start operation, and the usability of the material in tires and tubes. The biggest debate in regard to its manufacture has ranged around the best method for producing butadiene. Butadiene can be made successfully from crude oil, from refinery gases, or from alcohol obtained from potatoes, grains, sugar, molasses, etc., and it can be so obtained by a number of different processes. Any attempt to detail the methods for producing butadiene in use today would probably be obsolete within a few weeks because these processes are now being improved with a rapidity that startles comprehension.

In one generally used method, styrene is made from refinery gas and coal tar from which ethylene and benzol respectively are produced. These two substances are combined into ethyl benzene, and styrene is made from the ethyl benzene.

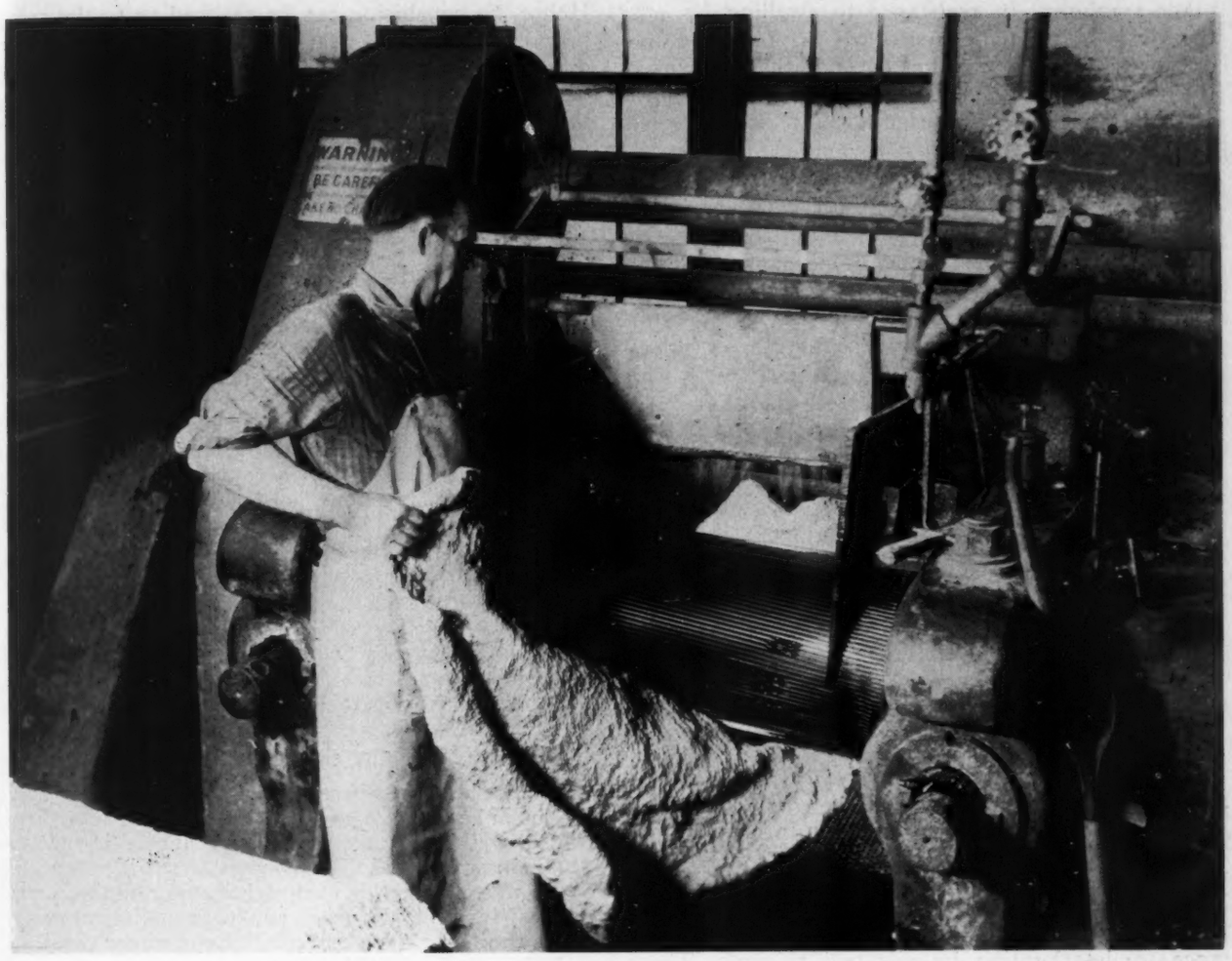
In the manufacture of Buna S, butadiene, styrene, water, emulsifiers from animal fats and a catalyst are introduced into a reactor where polymerization takes place. Buna S latex is produced and coagulation of this latex results in the crude material ready for the rubber manufacturer.

(5) *Isobutylene Interpolymers.* These materials produced by Standard Oil Company of New Jersey and Standard Oil Company of Louisiana, are derived from the interpolymerization of isobutylene and butadiene. Less is known about this synthetic than about any of the others, but it is generally understood that the basic structure of such an interpolymer is



Isobutylene itself is secured from refinery gas and has been used as a rubber extender under the trade name "Vistanex." The production of butadiene has been discussed. The introduction of isobutylene and butadiene with a catalyst into a polymerizer results in the polymerization of the isobutylene inter-

Men long familiar with natural rubber inspect Buna S



AMERIPOL

polymers. When first introduced, these materials were known as butyl. Recently, a process has been perfected for producing the material at a more rapid rate and the material so produced is known as "Flexon." The principal difference in the two processes is the temperature at which polymerization takes place. In producing butyl, polymerization is carried on at minus 153° F. In the Flexon process, this reaction takes place at minus 103° F.

A Variety of Materials

While only six types of synthetic rubber are listed here, it must be remembered that several of these types could be further broken down into subtypes, for example, the neoprenes, and that research on interpolymers is going ahead at an ever accelerating rate. It is entirely possible that within a few years new and improved synthetic rubbers which will obsolete some or all of these types will be introduced to the engineering profession.

In addition, each type of synthetic and each subtype under these major groupings must be compounded with other ingredients, processed and vulcanized. This means, first of all, that expert rubber knowledge and rubber making equipment is necessary to utilize the various synthetic rubbers. Of considerably more importance to the engineer considering the use of vulcanizates made from these synthetics is the fact that literally thousands of different compounds each utilizing a few of the hundreds of available compounding ingredients are possible with each synthetic rubber. Each of these compounds will have properties varying in some degree from each of the others. Each has a particular field of service and in that and associated fields will be eminently satisfactorily.

Properties of Synthetic Rubbers

Because of the wide range of properties possible through compounding, it is futile to try to compare the properties of synthetic rubbers in a general sense. About the only comparison that would be practical would be a comparison of a compound of each which had been carefully formulated to satisfy a certain set of service conditions. It would be necessary to process all of the compounds in exactly the same way in the same plant. Moreover, such a comparison would have to include compounds made from the various interpolymers of butadiene and chloroprene and the various types of the polysulfide rubber. Obviously, such a comparison of properties would not be of use to anyone except the man who was planning to use the exact product being considered under the exact conditions. Certain general comparisons are, however, possible. In the comparison, compounds of the material rather than the crude synthetic rubbers themselves are considered.

The polysulfide rubbers are superior to all the

other synthetics in resistance to swelling by oils, especially by aromatic hydrocarbons. They are also quite resistant to oxidation deterioration. However, they are inferior to natural rubber in tensile strength and in elastic recovery, especially at elevated temperatures. Despite these shortcomings, their excellent oil resistance has enabled their use in many industrial products and present-day experiments indicate their usability in the recapping of tires.

The chloroprene rubbers have mechanical properties (resilience, tensile strength, elasticity, abrasion resistance) quite comparable to those of natural rubber whether vulcanized in a pure gum type of formulation or compounded with carbon black as for tire treads. They have been manufactured into every type of product now being made from natural rubber. They are superior to natural rubber in resistance to deterioration by sunlight, heat, ozone, oxidation, alkalies, most acids, and oils. The degree of swell when exposed to oils depends upon the type of neoprene used and on the formulation, but, even more important, the chloroprene rubbers maintain a high percentage of their original properties after such exposure. Due to their chlorine content, they are relatively non-flammable. In regard to this synthetic, the Baruch committee said, "We recommend the construction of an additional plant for the production of neoprene to the extent of 20,000 tons a year capacity. We make this recommendation because neoprene is the one synthetic material of a quality to be the full equivalent of natural rubber for combat and heavy duty tires, either by itself or in combination with Buna S."

The Buna N types also are comparable to natural rubber in most physical properties. They are markedly superior to the natural product in resistance to deterioration by oils and solvents. These advantages fit these synthetic rubbers for industrial applications where the vulcanizates must maintain their formations virtually unchanged despite extended exposure to the deteriorating influences.

The Buna S type of synthetic rubber is not an oil and solvent resisting type. Its properties are quite similar to those of natural rubber when compounded with carbon black. This ingredient is universally used in all tire tread compounds and other rubber compositions required to have high resistance to abrasion. Hence tread type compounds made from Buna S compare favorably with tread compounds made from natural rubber. However, when compounded without carbon black, Buna S is inferior to natural rubber in tensile strength and in elasticity. It would not make good rubber bands or elastic garments. This synthetic has good resistance to chemicals and to aging, and has excellent electrical properties.

The isobutylene rubbers have excellent resistance to chemicals and to oxidation. They are well suited for electrical insulation and have a high resistance to the effects of heat. They tend, however, to lower resistance to distortion from continued pressure, and have only fair abrasion resistance. They have been introduced into the synthetic rubber picture so recently that exact details regarding their properties have not, as yet, been worked out.

The physical properties of all vulcanizates made from synthetic rubber or of natural rubber are greatly affected by the temperature of the test. Hence, no conclusion can be reached as to the relative tensile strength, tear resistance, elastic recovery or abrasion resistance of two or more compounds out of the thousands available without specifying the temperature of test or use. Further, any oils used for testing purposes must be specified exactly as two oils with the same SAE number made by different manufacturers from the same crude oil will have different effects on samples made from a single compound. Elasticity is also a function of direction and magnitude of the distorting force, and the time cycle of distortion and recovery. A sample of neoprene, for example, may under certain test conditions be more elastic than a rubber sample of similar type and be less elastic under other conditions of test or use. The danger of allowing oneself to reach conclusions of broader scope than the range of experiments justify is ever present in scientific and engineering investigations. This pitfall is nowhere more dangerous than in the study of the properties of rubber-like materials.

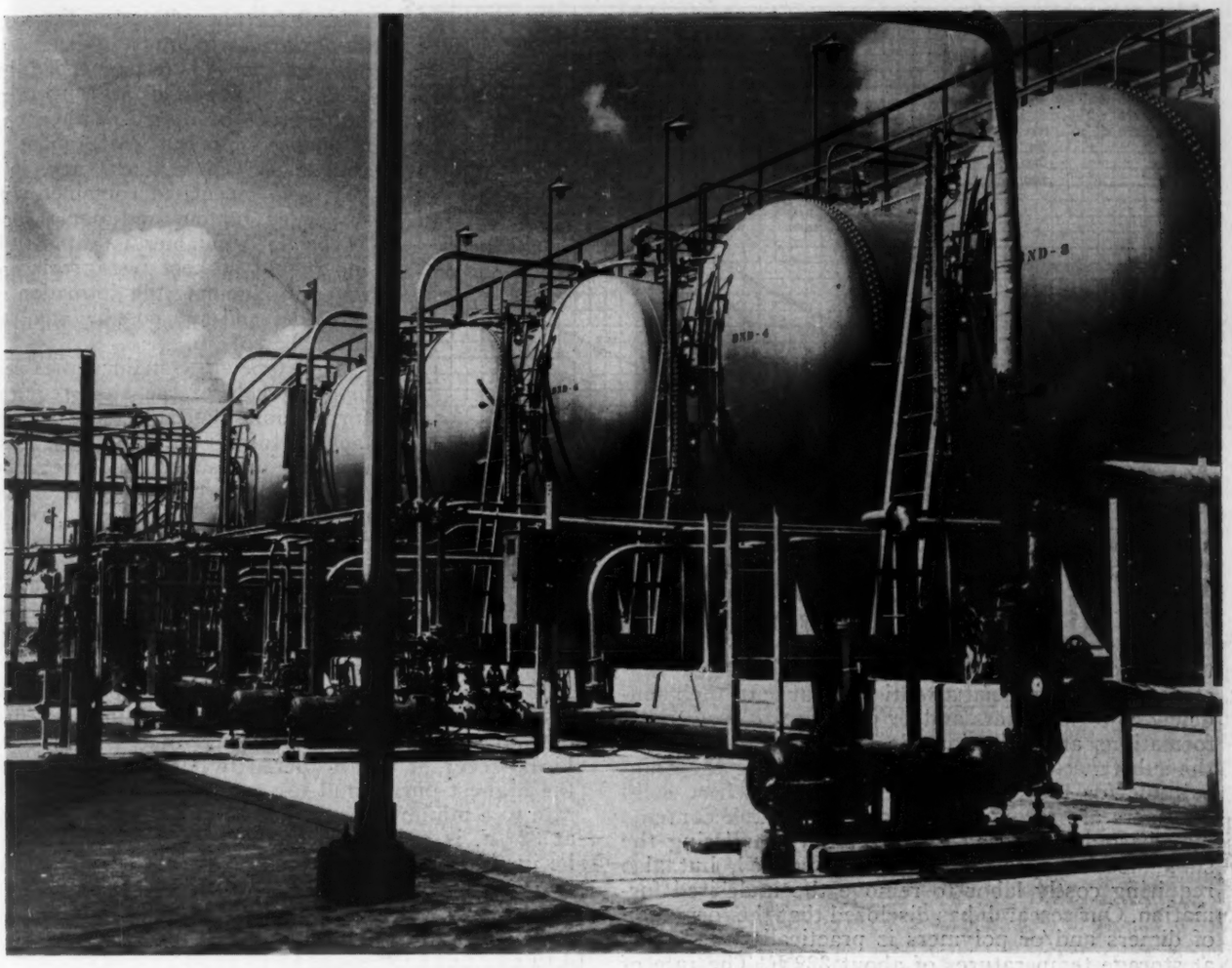
The safest procedure for an engineer to follow is to give all details regarding the proposed application to the manufacturer of the products and request parts which are to be placed in regular service. Then the engineer can keep a close check on the products in use and compare those results with a close check maintained on natural-rubber products used as a standard.

Definite Shortage Exists

It must be remembered when considering the synthetic rubbers that there is not today, nor will there be for well over a year, enough synthetic-rubber-producing capacity in this country to satisfy all needs of the war effort. This means that every engineer has the responsibility of using products made from synthetic rubber in the most intelligent manner possible, and of so designing his parts and specifying his materials that maximum service is secured from each product in service.

Aside from the lack of supplies, synthetic rubber will do the jobs required by industry, and, as has been proved by past experience, will do many of these in a better manner than they were ever done before. By the time we have won the war, an ever increasing number of engineers will know synthetic rubber and will appreciate its value. This means that it is the urgent job of every engineer to acquaint themselves with the true facts regarding the synthetics and to experiment with these products in the machinery and equipment he is making or using in the drive to produce the material needed by our armed forces.

It also should be remembered that synthetic-rubber products are going to cost more than natural-rubber products. Whether they will pay for themselves when compared with the products previously used depends upon the conditions of service and the synthetic-rubber compound used, but the point is of little moment at this time. In the future, it is extremely doubtful that synthetic rubber can compete with natural rubber on a free economy basis. When the time comes to consider this factor, we can rest assured that our oil and chemical industry will be prepared to produce the best types of synthetic that can be devised and that those synthetics will earn their proper position in industry regardless of any competition from the natural product.



Storage and Handling of Butadiene, Isobutylene, Styrene, and Acrylonitrile

JAMES B. GARNER, LUDWIG ADAMS, and ROBERT M. STUCHELL
Multiple Industrial Fellowship on Chemical Storage, Mellon Institute of Industrial Research

BECAUSE of the importance of synthetic rubber to the war program, the Pittsburgh-Des Moines Steel Company, through its Chemical Storage Fellowship at Mellon Institute of Pittsburgh, has made a comprehensive study of the storage and handling of butadiene, isobutylene, styrene, and acrylonitrile, the four most common chemical substances used in relatively large quantities in the production of synthetic rubber. This study consisted of (1) a search of the available literature, (2) the compilation of data from several cooperating organizations to establish the physical and chemical characteristics of the four substances, and (3) experimental work to determine the corrosive effect of the stored substances upon steel containers and also the effect of the steel containers on the stored substances.

Butadiene and isobutylene are gases at the normally prevailing temperatures and at atmospheric pressure. If they are to be stored at these temperatures they must therefore be stored in containers capable of withstanding considerable internal pressure. They may, however, be stored in insulated containers at low temperatures and at little or no internal pressure. Acrylonitrile and styrene are liquids at normal temperatures and pressures, and therefore may be stored in containers such as are used for water, gasoline, crude oil, etc., provided there is due consideration of their specific properties. In addition

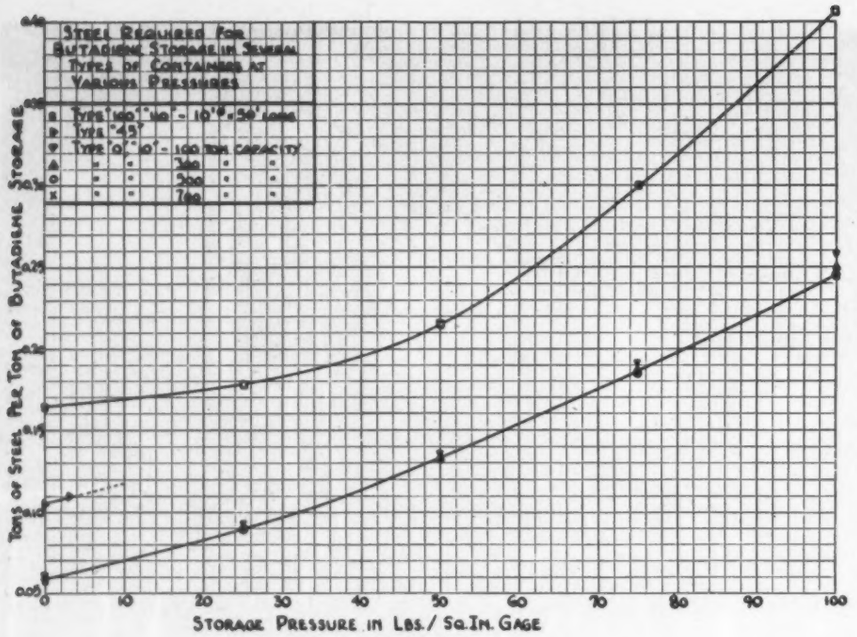

Steel Required for Butadiene Storage in Several Types of Containers at Various Pressures
a Type "140" - 140° - 10'-0" - 50' long
b Type "45"
y Type "0" - 30' - 100 ton capacity
A " " 300 " "
O " " 300 " "
K " " 700 " "
Tons of Steel per Ton of Butadiene Storage
Storage Pressure in Lbs./Sq.In. Gage

FIGURE 1

to the factors of temperature and pressure these substances require special attention because of their tendency to form dimers and/or polymers. These transformations are objectionable because the nature of the substances is changed, usually making them unsuitable for the purpose intended; and where solid polymers are formed a portion of the tank contents may become solidified, thus not only rendering the substances useless, and therefore wasted, but also requiring costly labor to remove the undesired formation. Our research has disclosed that the formation of dimers and/or polymers is practically eliminated at storage temperatures of about 32° F. The rate of polymerization of butadiene, for example, is less than 1/40 as rapid at 32° F. as at 140° F.

Economic considerations are also important. The initial cost of storage containers of different types may vary by several hundred percent.

The annual operating cost may likewise vary considerably. The amount of steel needed for different types of containers also varies, some types requiring less than one-half as much steel as others. The amount of steel required is a very important consideration at present. In selecting the most economical type of storage it is very important that attention be given to the condition under which the storage plant will operate. For example, if the product is made at the plant and is available for storage at low temperature, the economical type of container will be probably much different from another plant where the product is received in tank cars. The availability of refrigeration is also an important factor. Several charts have been prepared which, it is believed, will be helpful in selecting the economical type of storage for any given conditions. Data are included to facilitate the determination of initial and annual costs of refrigeration based on the number of anticipated fillings. In general the containers should be as large as possible because the cost per ton of product becomes smaller as the container capacity increases.

Specific Recommendations

Specific recommendations for the substances considered for normally prevailing conditions are as follows:

Butadiene: It is recommended that butadiene be stored at a working temperature of 32° F. with a corresponding pressure of about 3 pounds per square inch gage, in a "Type 45" insulated container with suspended bottom and dome roof. "Type 45" container is vapor-tight and should be kept free of air and water to eliminate the formation of peroxides and any possible catalytic effect thereof.

This type of container uses less than one-half of the steel required for an uninsulated pressure storage tank, resulting in an annual cost, including investment and operation, of about 25 percent less than any of the other types considered. At the recommended temperature the rate of polymerization is negligible.

Isobutylene: The recommendations made for butadiene generally apply for isobutylene, as the two substances have very similar physical properties.

Styrene: Styrene, because of its low vapor pressure, may be most economically stored in cylindrical, flat-bottom, dome- or cone-roof, uninsulated containers. If, however, it is considered important to maintain the highest purity and to reduce the polymerization rate to a minimum, storage in an insulated container at 32° F. is only slightly more expensive and may be justified. It is most important that storage tanks

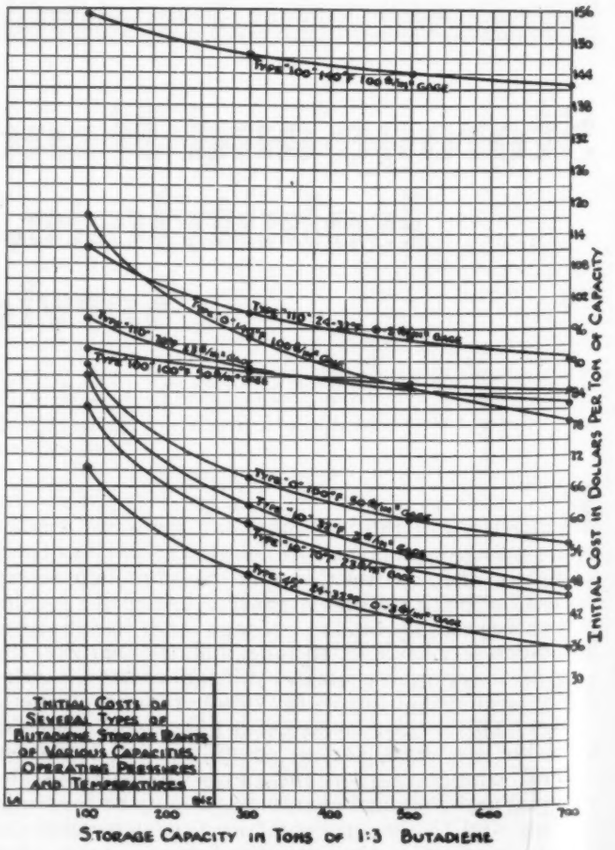

Initial Costs of Several Types of Butadiene Storage Units of Various Capacities, Operating Pressures and Temperatures
Initial Cost in Dollars per Ton of Capacity
Storage Capacity in Tons of 1:3 Butadiene

FIGURE 2

containing styrene be free of air and be maintained at as low a temperature as is economical.

Acrylonitrile: The recommendations for styrene generally apply also to acrylonitrile, which also has a very low vapor pressure at storage temperatures. In addition, the vapors of acrylonitrile are highly toxic. Air and water should be removed.

Figure 1 shows the amount of steel required per ton of butadiene or isobutylene for storage at various pressures. It will be noted that the size of the container has little influence on the amount of steel required. The type of container, however, has a very important influence.

Figure 2 shows the initial cost of several types of butadiene- or isobutylene-storage plants of various capacities, operating pressures and temperatures. The "Type 45" insulated tanks are appreciably lower in initial cost than the other types considered. The costs shown are based upon current prices and labor rates and are for plants located in the Pittsburgh district. These costs will vary somewhat at other locations.

Figure 3 presents the annual operating costs of several types of butadiene and isobutylene storage plants of various capacities, operating pressures and temperatures. The annual operating cost of the "Type 45" insulated tank is lower than the other types considered. Figure 4 is a chart to be used in determining the approximate initial cost of a refrigeration plant for the precooling of butadiene or isobutylene for storage. Figure 5 is a chart for determining the annual fixed cost of a refrigeration plant for the precooling of butadiene or isobutylene for storage. Figure 6 is for use in ascertaining the annual operating cost of a refrigeration plant for the precooling of butadiene or isobutylene for storage. Figures 4, 5 and 6 should be used to determine the most economical storage temperature in cases where the product is made or received at a temperature higher than the most economical storage temperature of about 32° F.

In making such a comparison the initial cost of the precooling plant is added to the initial cost of the container considered, and the fixed annual cost and

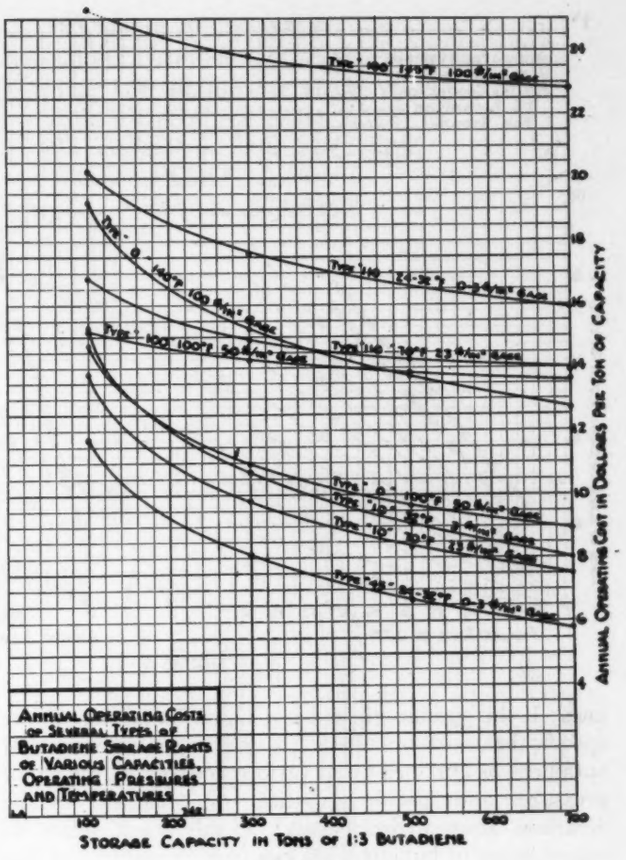

Annual Operating Costs of Several Types of Butadiene Storage Plants of Various Capacities, Operating Pressures and Temperatures
Annual Operating Cost in Dollars Per Ton of Capacity
Storage Capacity in Tons of 1:3 Butadiene

FIGURE 3

the operating annual cost of the precooling refrigeration plant is added to the annual cost of the type of container being considered for comparison with similar figures made for other types or operating temperatures. The most economical combination of plant type and operating temperature can be determined in this manner. Figure 7 is representative of the design of a "Type O" container, an uninsulated and unrefrigerated spherical tank used to store liquids and gases under pressure. Figure 8 represents the design of a "Type 10" container, an insulated and refrigerated tank, but otherwise identical with "Type O." Figure 9 illustrates the design of "Type 45" container, an insulated and refrigerated double-walled cylindrical vessel with suspended bottom and dome roof, at working pressures under 10 pounds per square inch, gage. Figure 10 is representative of the design of a "Type 100" container, which is an uninsulated and unrefrigerated horizontal cylindrical container, 10 feet in diameter by 50 feet long, used for storage of liquids. This type is used in groups of 2, 5, 8, and 10 to make up the required 100-, 300-, 500- and 700-ton capacities. Figure 11 is representative of the design of a "Type 110" container, insulated and refrigerated, but otherwise identical with "Type 100."

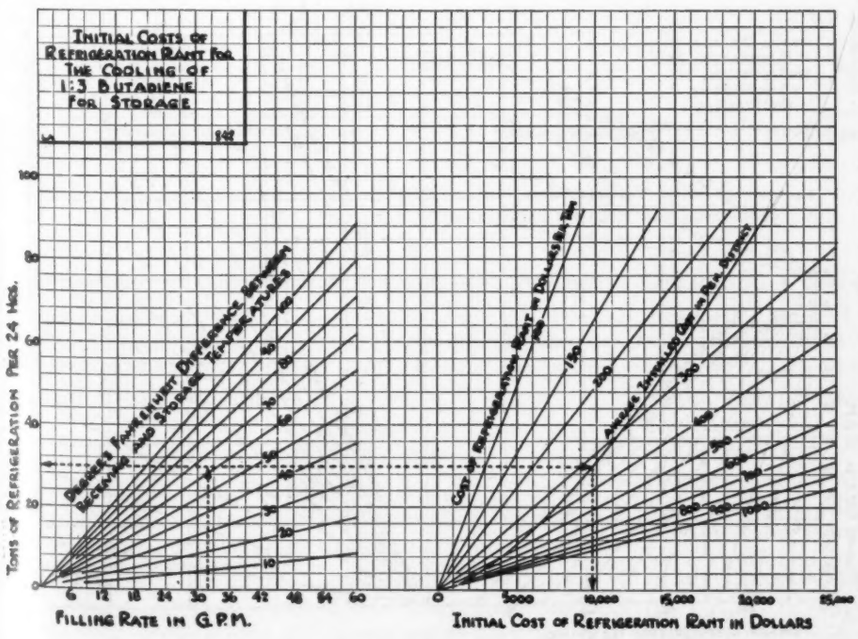

Initial Costs of Refrigeration Plant for the Cooling of 1:3 Butadiene for Storage
Tons of Refrigeration per 24 Hrs.
Filling Rate in G.P.M.
Initial Cost of Refrigeration Plant in Dollars

FIGURE 4

The graphic charts are as fol-

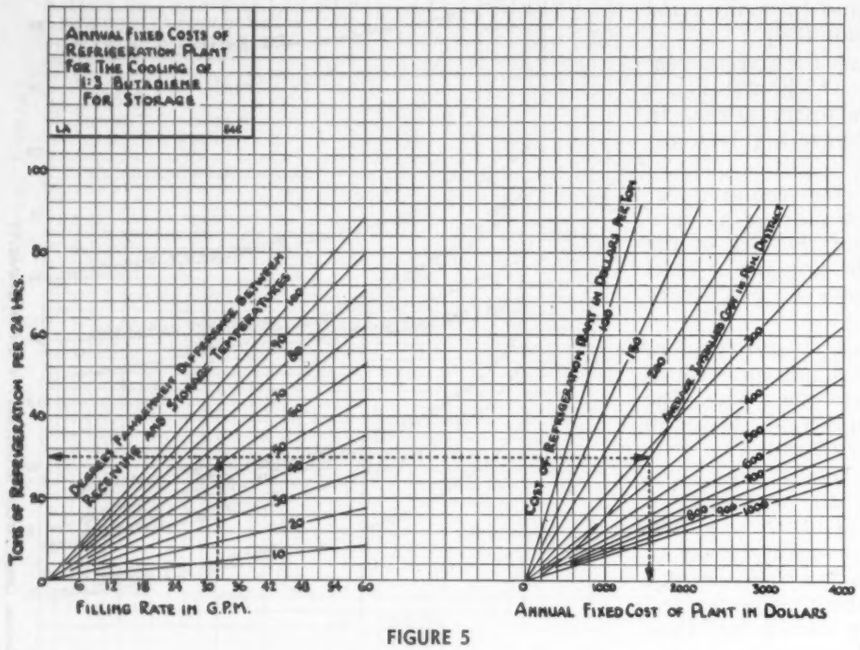

Annual Fixed Costs of Refrigeration Plant For The Cooling of 1:3 Butadiene For Storage
Tons of Refrigeration per 24 Hrs.
Filling Rate in G.P.M.
Annual Fixed Cost of Plant in Dollars

FIGURE 5

lows: 1, the specific gravities of liquid butadiene; 2, the specific heats of butadiene; 3, the vapor pressures of butadiene as obtained from various sources; 4, the vapor pressures and specific gravities (or densities) of the 4-carbon atom hydrocarbons; 5, the latent heats of vaporization of butadiene; 6, the vapor pressures of isobutylene; 7, the vapor pressures of styrene; and 8, the vapor pressures of acrylonitrile.

Physical Properties

Careful studies have been made of the literature having to do with the physical properties of these four substances. Cooperative sources of information have been consulted. The available data have been appraised and only those which seem to meet general acceptance—all based upon experimental work—are herewith set forth.

Chemical Properties

All the substances are very reactive chemically and undergo a class of chemical changes, technically called dimerization and polymerization. These changes occur under a variety of conditions. However all such changes are accompanied by the evolution of heat. All these substances contain the characteristic olefine groupings and as such undergo the corresponding reactions. Air or oxidizing materials, either acidic, aliphatic, or inorganic, tend to form peroxides or other substances which have no value in the production of synthetic rubber. Light has a noteworthy effect on styrene and acrylonitrile. Heat accelerates dimerization and/or polymerization. The following substances are known as catalyzers, that is, substances which, although they do not participate directly in the change, yet accelerate the rate of chemical alteration:

Butadiene: Stannic chloride, metallic sodium and other alkali metals, alkaline earth metals, amalgams or alloys of these metals, colloidal platinum, mercury or silver or manganese dioxide, metallo-organo compounds, boron trifluoride, barium peroxide, hydrogen peroxide, sodium perborate, ammonium persulfate, organic peroxides, organic peracids, sulfur, starch, oleates of sodium, ammonium, and cobalt, sodium stearate, albumen, casein, urea, soap, saponine, glycerine, and dioxan.

Isobutylene: Inorganic acids, silicates, aluminum chloride, and boron trifluoride.

Styrene: Air, oxygen, ozone, sunlight, ultra-violet, heat, peroxides, di-isobutylene ozonide, metallic halides—as stannic chloride, antimonic chloride, aluminum chloride-boron trichloride, boron trifluoride, sulphuric acid, hydrogen chloride, and metallic sodium.

Acrylonitrile: Careful and comprehensive studies relative to the catalytic reagents of acrylonitrile have not been made and published, as has been the case with butadiene and styrene. The general experience, however, has been that the catalyzers and inhibitors of styrene are equally effective with acrylonitrile.

The following are inhibitors, that is, substances which retard or prevent polymerization changes:

Butadiene: Tertiary butyl catechol, hydroquinone, tricresol, *B*-phenyl-naphylamine, diarylamines, 1, 8 diamino naphthalene.

Styrene: Hydroquinone, benzoquinone, sulfur, aromatic nitro compounds, anthracene, pyridine, methyl aniline, pyrogallol and other polyhydric phenols, *B*-

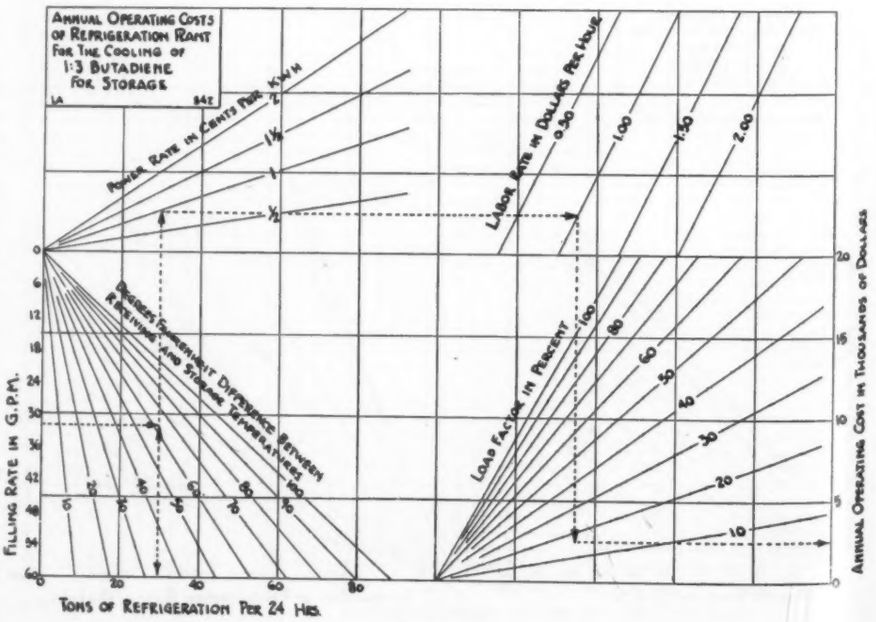

Annual Operating Costs of Refrigeration Plant For The Cooling of 1:3 Butadiene For Storage
Power Rate in Cents per KW H
Labor Rate in Dollars per Hour
Load Factor in Percent
Filling Rate in G.P.M.
Tons of Refrigeration per 24 Hrs.
Annual Operating Cost in Thousands of Dollars

FIGURE 6

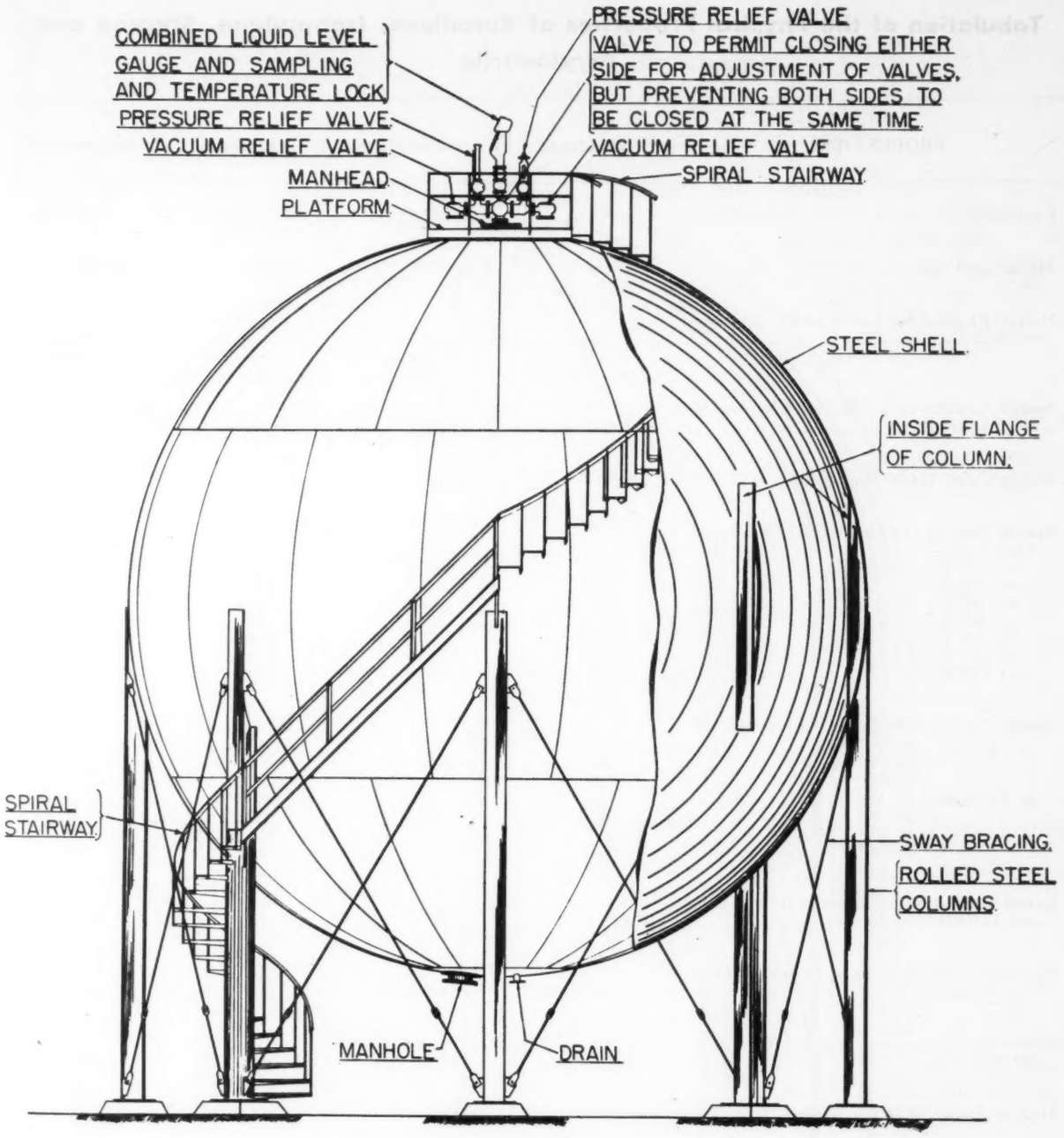


FIGURE 7
Non-Insulated Spherical Container—Type "O"

naphthylamine, hydrazobenzene, phenanthroquinone, bromine, iodine, picric acid, *B*-Phenyl-naphthylamine, 1.5 dihydroxynaphthalene, guaiacol, picramide, dinitrobenzene, trinitrobenzene, para-formaldehyde, hexamine, and 1.2 diaminopropane.

Annual Operating Costs

The annual operating costs consist of: (1) investment charges, (2) taxes, (3) maintenance and repair, (4) supplies and miscellaneous, and (5) power, light and fuel.

The investment charges for the containers, accessories, and foundations are based upon 20-year life, 10 percent salvage value, 4 percent sinking-fund interest, and 4 percent bond interest, for a combined figure of 7 percent of the initial cost. The investment charges for the corkboard, used on the single-wall containers, are based upon a 10-year life, no salvage value, 4 percent sinking fund interest, and 4 percent bond interest, for a combined figure of 6.7 percent of the initial cost of the insulation. The investment charges for the refrigeration plant are based upon a 20-year life, 10 percent salvage value, 4 percent sinking fund interest, and 4 percent bond interest, for a combined figure of 7 percent of the initial cost of the refrigeration plant. The taxes will vary with the locality. Computations are based upon 4 percent. Maintenance and repair vary from 4 to 10 percent depending upon the type of plant and the load factor.

Tabulation of the Physical Properties of Butadiene, Isobutylene, Styrene and Acrylonitrile

PROPERTIES	Butadiene	Isobutylene	Styrene	Acrylonitrile
1. Formula	C_4H_6	C_4H_8	C_8H_8	C_3H_3N
2. Molecular Weight	54.088	56.100	104.140	53.060
3. Normal Physical State at 14.74 lbs./sq. in. and 60° F.	Gas Colorless Aromatic Odor	Gas Colorless Odorous	Liquid Colorless Penetrating Odor	Liquid Colorless Odorous
4. Specific Gravity as a Gas (14.74 lbs./sq. in., 60° F.) Air = 1	1.877	2.011	3.604*	1.838*
5. Boiling Point (14.74 lbs./sq. in.) °F.	23.54 [1]	22.28 [1]	294.80 [8]	170.6 [14]
6. Specific Gravity as a Liquid (14.74 lbs./sq. in.) water = 1:				
at 0° F.	.6620 [2]	.6388 [6]	.9410	.8478 [5]
at 24° F.	.6473	.6252	.9297	.8330
at 32° F.	.6425	.6200	.9259	.8281
at 60° F.	.6263	.6043	.9127	.8110
at 70° F.	.6205	.5991	.9080	.8048
at 100° F.	.6023	.5810	.8938	.7863
at 140° F.	.5780	.5575	.8749	.....
7. Specific Heat (14.74 lbs./sq. in.) Btu/lb./°F.				
a. Cp. Gas at 24° F.	.308 [2]	.....	.....	.....
at 60° F.	.332	.366	.....	.....
at 100° F.	.356	.....	.....	.....
b. Cp. Liquid at 24° F.	.518	.....	.3947 [10]	.....
at 60° F.	.551	.555	.4023	.50 ± .03 [5]
at 70° F.	.560	.....	.4050	.....
at 100° F.	.588	.....	.4130	.....
8. Latent Heat of Vaporization at Boiling Point and 14.74 lbs./sq. in. Btu/lb.	174.75 [2]	172.50 [1]	153.00 [11]	265 [5]
9. Coefficient of Expansion as a Liquid between —5° F. and 70° F.	.001022/°F. [1]	.00104/°F. [1]	.0004717/°F. [2]	.0006144/°F. [5]
10 Inflammability Limits. Volume Percent in Air Mixture	2.0 to 11.5 [3]	1.7 to 9.0 [7]	1.1 to 6.1 [8]	3.05 to 17.1 [14]
11. Melting Point (14.74 lbs./sq. in.) °F.	—163.67 [3]	—232.2 [1]	—25.6 [4]	—118.3 [5]
12. Critical Temperature °F.	+325.7 [4]	303 [15] +292.5 [1]	.....	.....
13. Pounds of Liquid per U.S. Gallon at 60° F.	5.220 [4]	5.0396	7.6156	6.75*
14. Vapor Pressure lbs./sq. in. Absolute:				
Maximum at —100° F.	.3588 [5]	.4736 [6]	.....	.....
Vapor at — 50° F.	2.1637	2.414	.....	.....
Data at + 32° F.	17.650	18.784	.02307 [13]	.6013 [14]
Communicated at + 70° F.	38.468	39.1	.089	1.734
at +100° F.	65.874	.....	.235	3.606
at +140° F.	124.20	.....	.8728	8.048
Mean Vapor Pressure (absolute):				
Data (all sources) at —100° F.	.35			
at — 50° F.	2.00			
at 0° F.	8.00			
at 32° F.	17.64			
at 70° F.	37.70			
at 100° F.	64.70			
at 140° F.	114.70			

* Calculated.

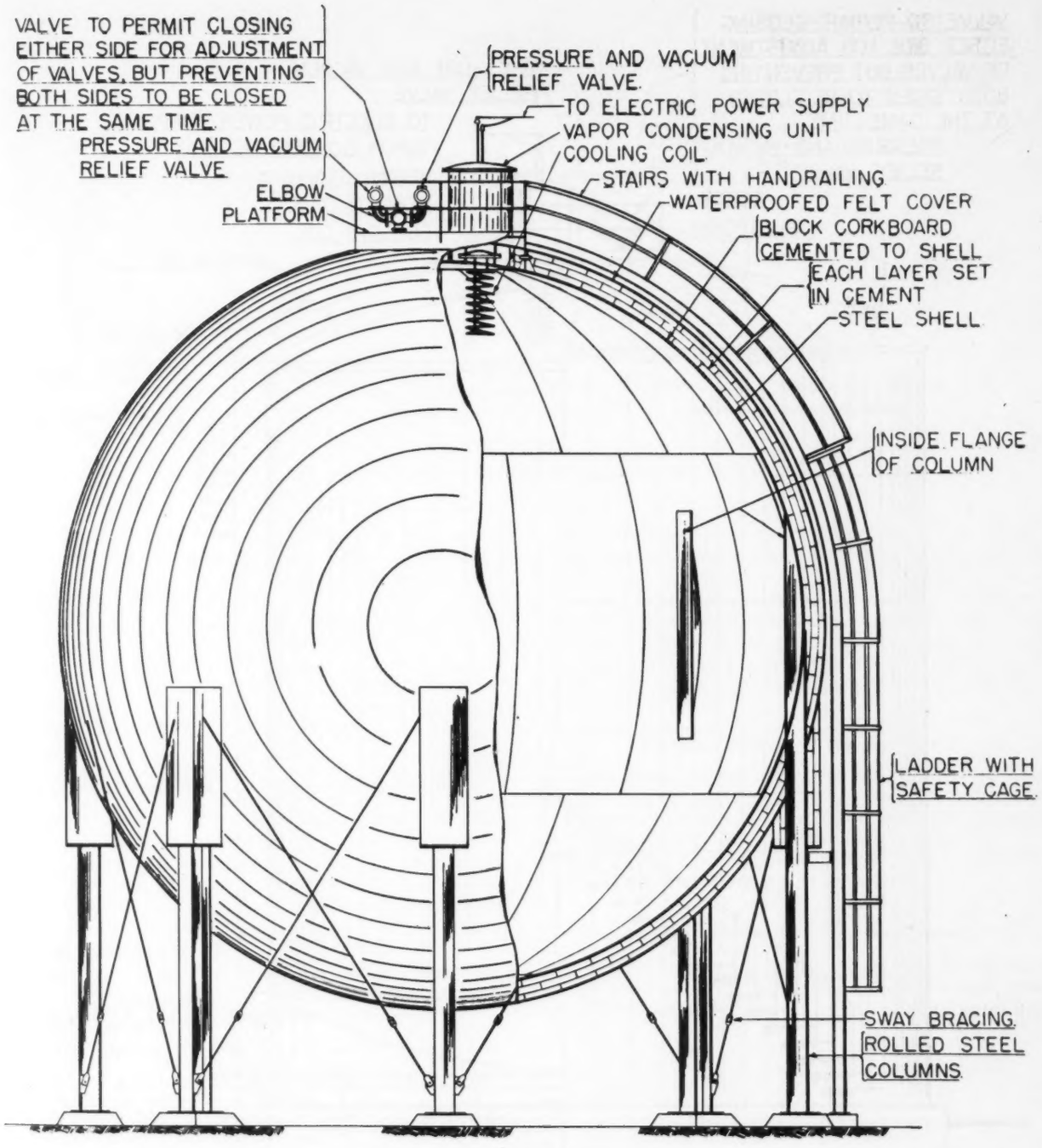

VALVE TO PERMIT CLOSING EITHER SIDE FOR ADJUSTMENT OF VALVES, BUT PREVENTING BOTH SIDES TO BE CLOSED AT THE SAME TIME.
PRESSURE AND VACUUM RELIEF VALVE
ELBOW
PLATFORM
PRESSURE AND VACUUM RELIEF VALVE.
TO ELECTRIC POWER SUPPLY
VAPOR CONDENSING UNIT
COOLING COIL
STAIRS WITH HANDRAILING
WATERPROOFED FELT COVER
BLOCK CORKBOARD CEMENTED TO SHELL
EACH LAYER SET IN CEMENT
STEEL SHELL
INSIDE FLANGE OF COLUMN
LADDER WITH SAFETY CAGE
SWAY BRACING
ROLLED STEEL COLUMNS

FIGURE 8

Insulated Spherical Container—Type "O"

Computations are based upon 4 percent. Supplies and miscellaneous amount to about 1 percent of the initial cost. Power, light, and fuel costs are based upon prevailing rates.

Filling Refrigeration Costs

Where the substances are received for storage at temperatures higher than the storage temperature, the substances must be cooled down to storage temperature by a refrigeration plant which is built for that specific purpose or which is a part of the regular equipment of the synthetic rubber plant. The refrigeration capacity depends upon: (1) the degrees Fahrenheit difference between the receiving and storage temperatures; (2) the densities of the substances; (3) the desired filling rate in gallons per minute; and (4) the specific heats of the substances. The initial cost of the filling refrigeration plant is subject to the usual fluctuation in the cost of materials and labor. The annual fixed cost is made up of 7 percent for the investment charges, 4 percent for taxes, 4 percent for maintenance and repair, and 1 percent for supplies and miscellaneous, or a total of 16 percent. The annual operating costs consist of the cost of power, labor, and administration. Power is estimated at $0.01 per kilowatt hour, labor at $1.00

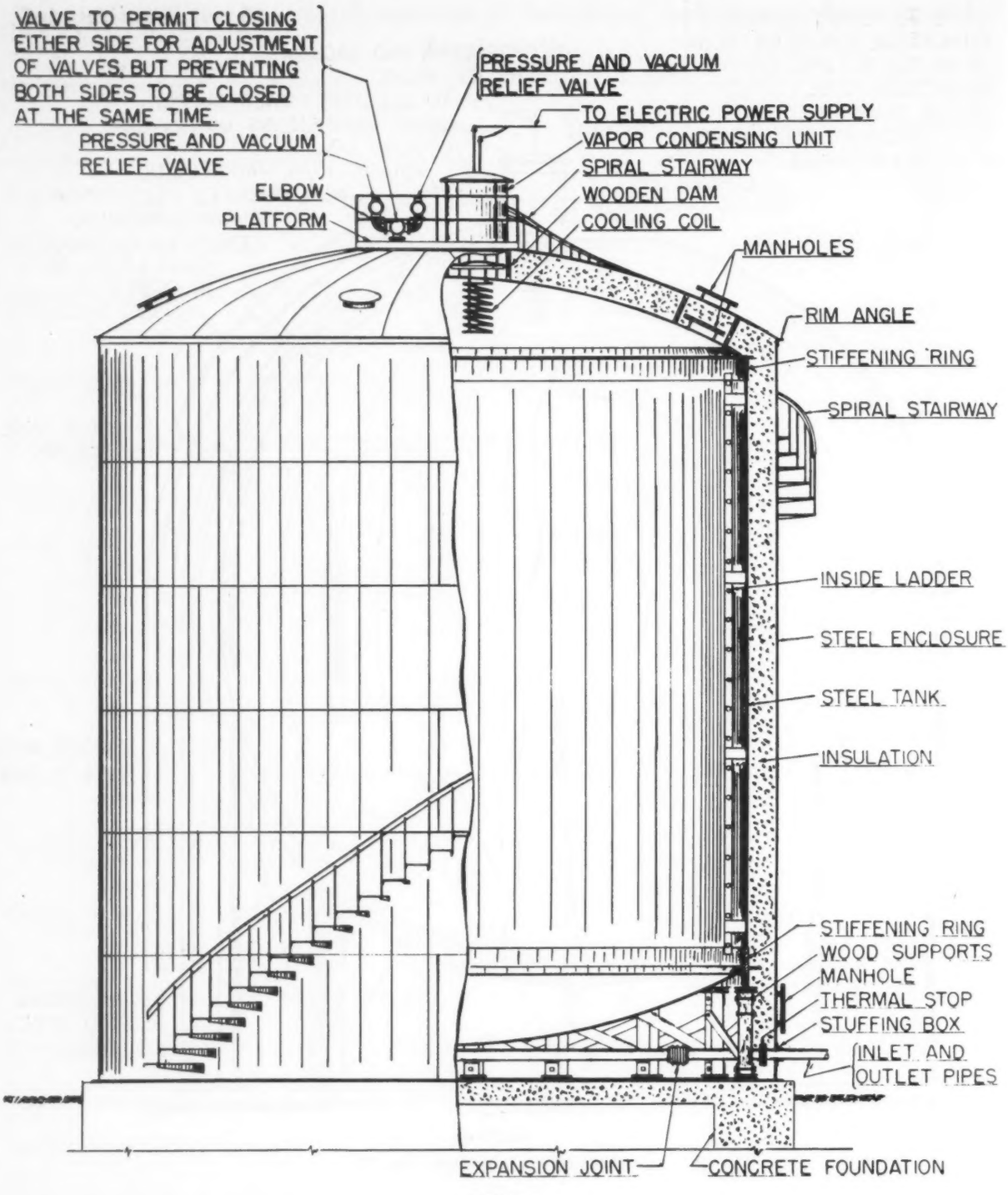


FIGURE 9
Insulated Container—Type "45"

per hour, and administration at 50 percent of the labor cost.

Corrosive Effects of Container Materials

The four substances—butadiene, isobutylene, styrene, and acrylonitrile — do not apparently corrode mild steel, stainless steel, or tin coating. Copper, lead, magnesium and aluminum, and their alloys are variously reported to catalyze and accelerate chemical changes in these substances. Comprehensive tests are being made to find the facts. Our results, so far obtained, clearly indicate the need of further research regarding the effect of various metals, alloys and coatings upon these substances.

Polymerized products are often found in containers in which these four substances have been shipped. This condition is believed to be due largely to the presence of air during the filling of the containers. To avoid this polymerization the container should be cleaned, dried, and purged with an inert gas, such

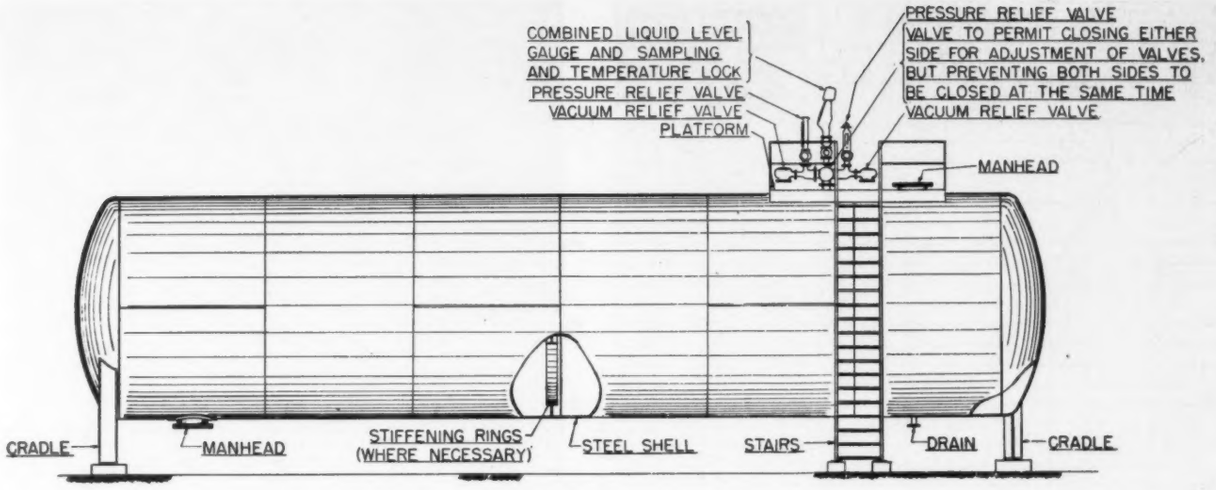


FIGURE 10

Non-Insulated Horizontal Container—Type "100"

as dry natural gas or nitrogen. Neither mill scale nor iron rust have any apparent effect upon these substances nor does finely divided iron oxide seem to have any effect upon emulsion polymerization when such polymerization is carried out on the alkaline side. However, if the emulsion polymerization is carried out on the acid side, iron compounds have a marked effect and the iron compounds therefore should be removed by filtration prior to use in the manufacture of synthetic rubber.

Physiological Effects and Preventative Handling

Acrylonitrile has noteworthy toxic properties. Butadiene and isobutylene have been observed by our experimenters to have some decided physiologically detrimental effect. This effect seems to vary noticeably with the individual. Blurring of vision and nausea are the characteristic symptoms so far noted. Some of our associates in the Mellon Institute are engaged in a careful analysis of the physiological effects of these substances and the results of this investigation will be available later on.

All four substances are inflammable. The United States Bureau of Mines has determined the explosive limits in air, which are contained in the tabulation of physical properties given in this article. In general the same precautions should be observed in the handling and use of these substances as are followed with manufactured gas and the volatile inflammable liquids, such as propane, butane, gasoline, and benzene.

Deterioration During Storage

If the precautions are observed relative to air, light, water, heat, and catalyzing reagents and inhibitors, these substances in storage will not undergo material deterioration if kept as recommended, for periods of 35 or less number of days. This statement is based upon preliminary experiments.

Transportation—Kind of Containers

Interstate shipments of butadiene and isobutylene are made in steel cylinders and insulated steel tank cars. Tank cars designated as ICC 104A are pre-

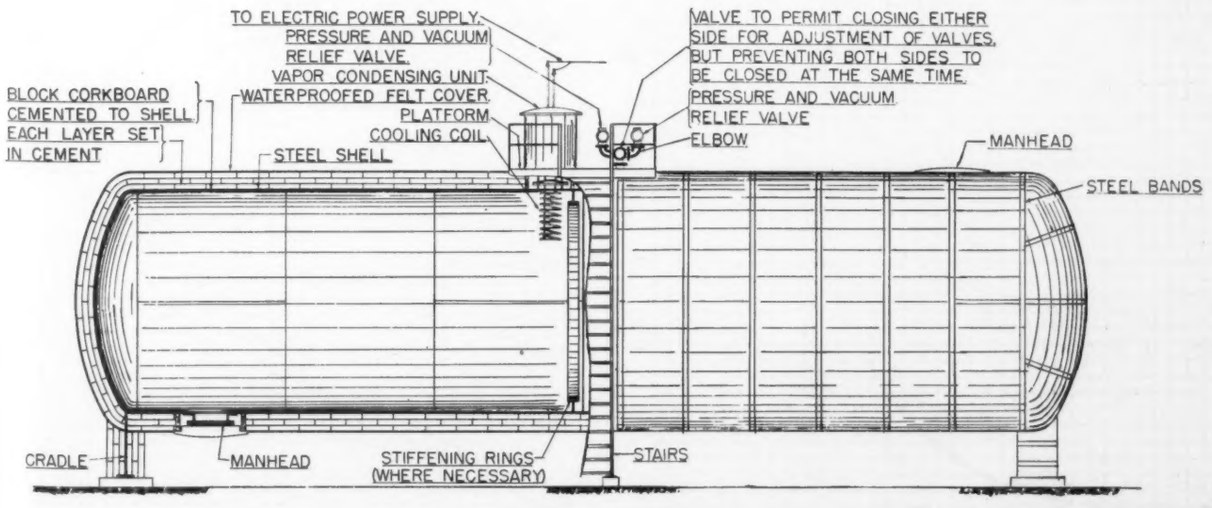


FIGURE 11

Insulated Horizontal Container—Type "100"

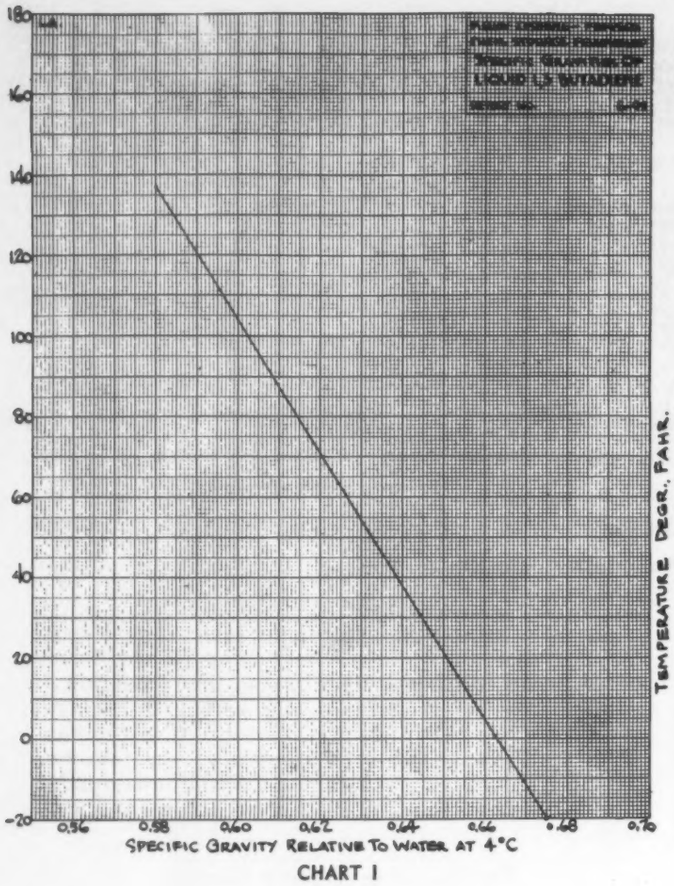


CHART I

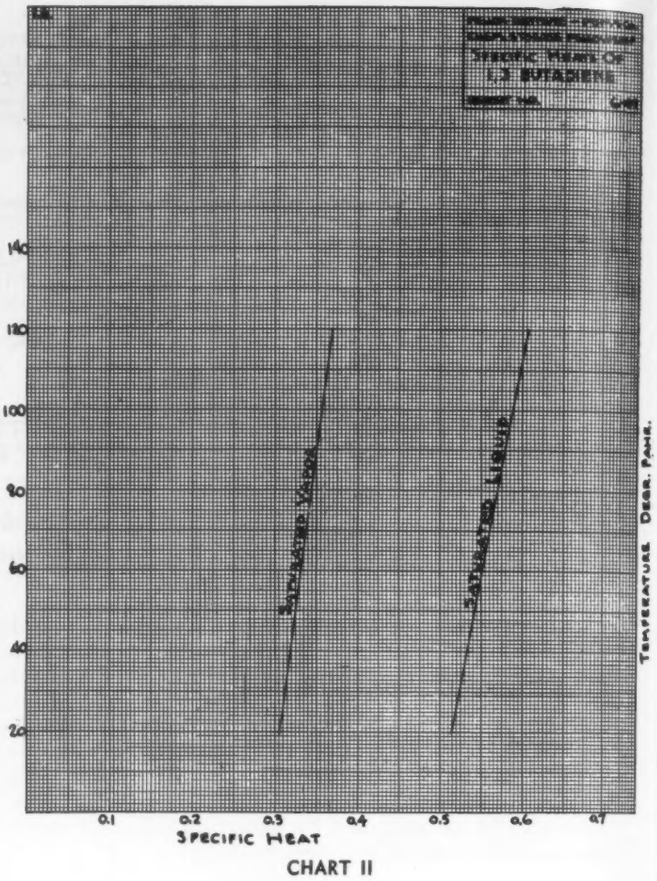


CHART II

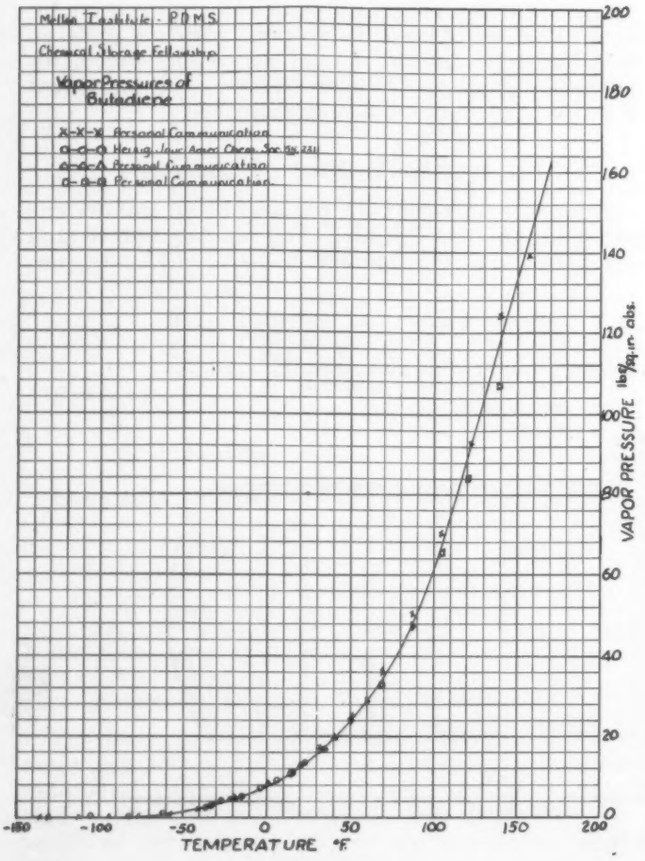


CHART III

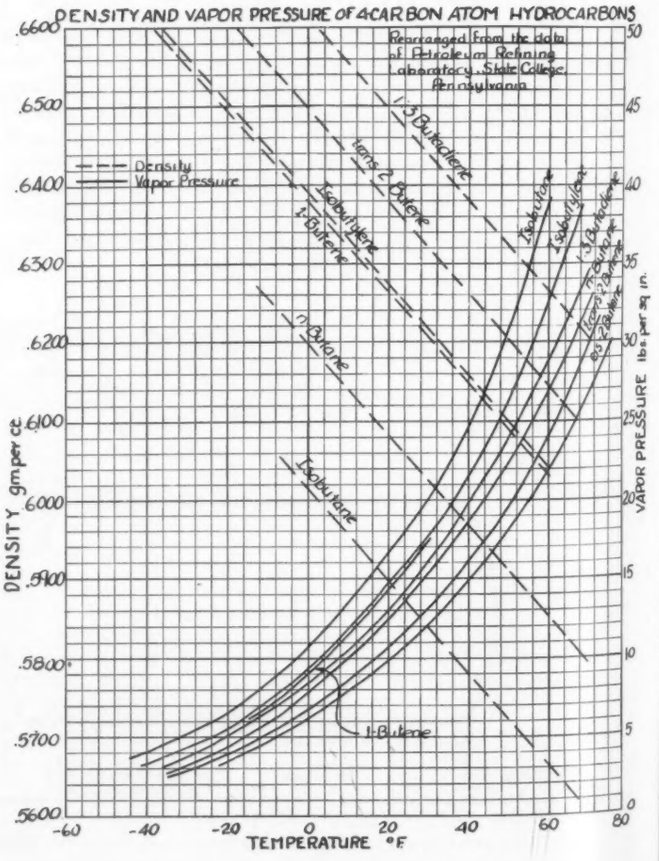


CHART IV

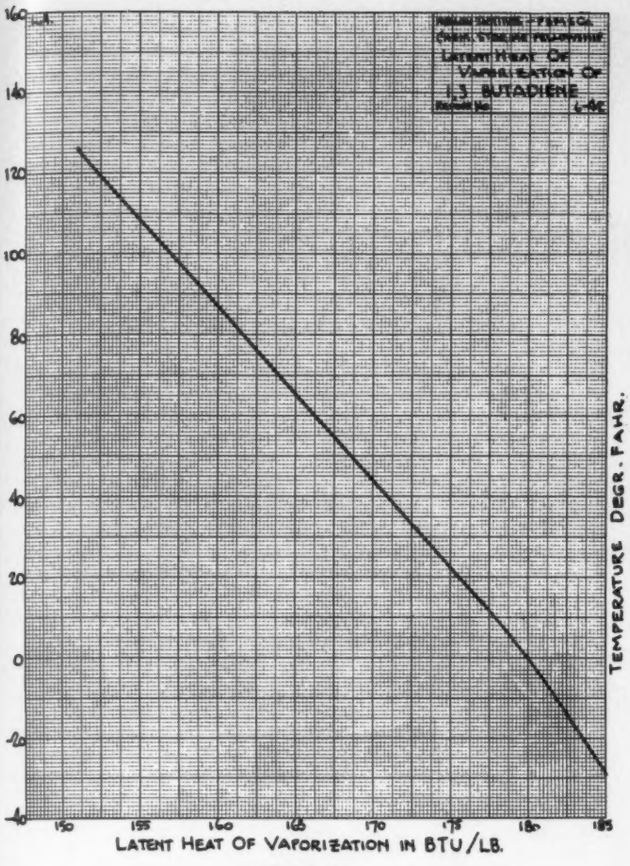


CHART V

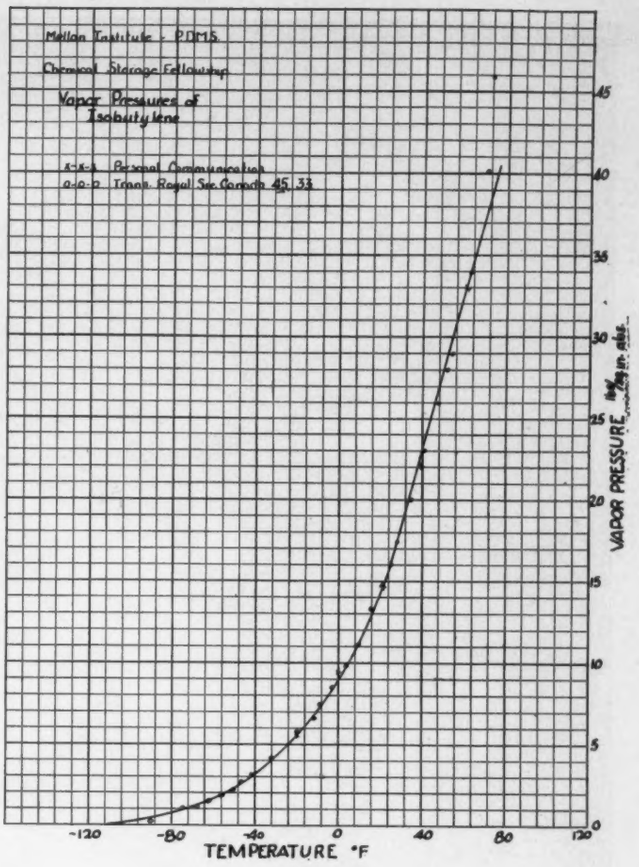

Mellon Institute - P.D.M.S.
Chemical Storage Fellowship
Vapor Pressures of Isobutylene
x-x-x Personal Communication
o-o-o Trans. Royal Soc. Canada 45, 33
VAPOR PRESSURE lbs/sq in. abs.
TEMPERATURE °F

CHART VI

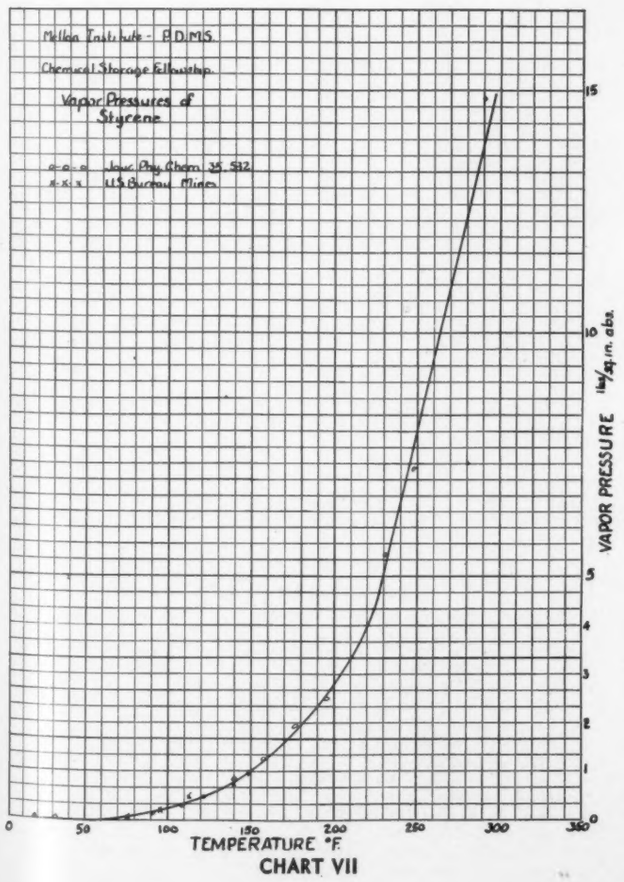

Mellon Institute - P.D.M.S.
Chemical Storage Fellowship
Vapor Pressures of Styrene
o-o-o Jour. Phy. Chem. 35, 512
x-x-x U.S. Bureau Mines
VAPOR PRESSURE lbs/sq in. abs.
TEMPERATURE °F

CHART VII

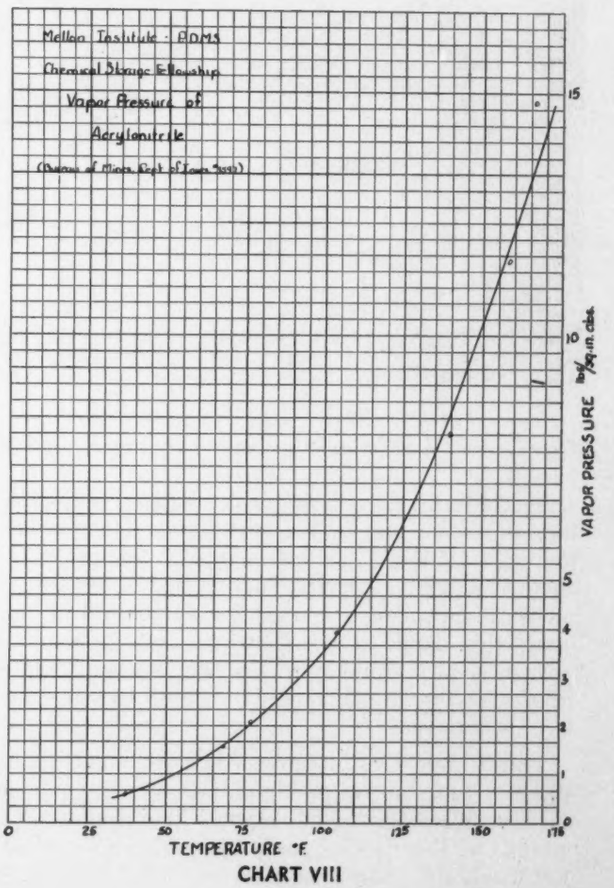
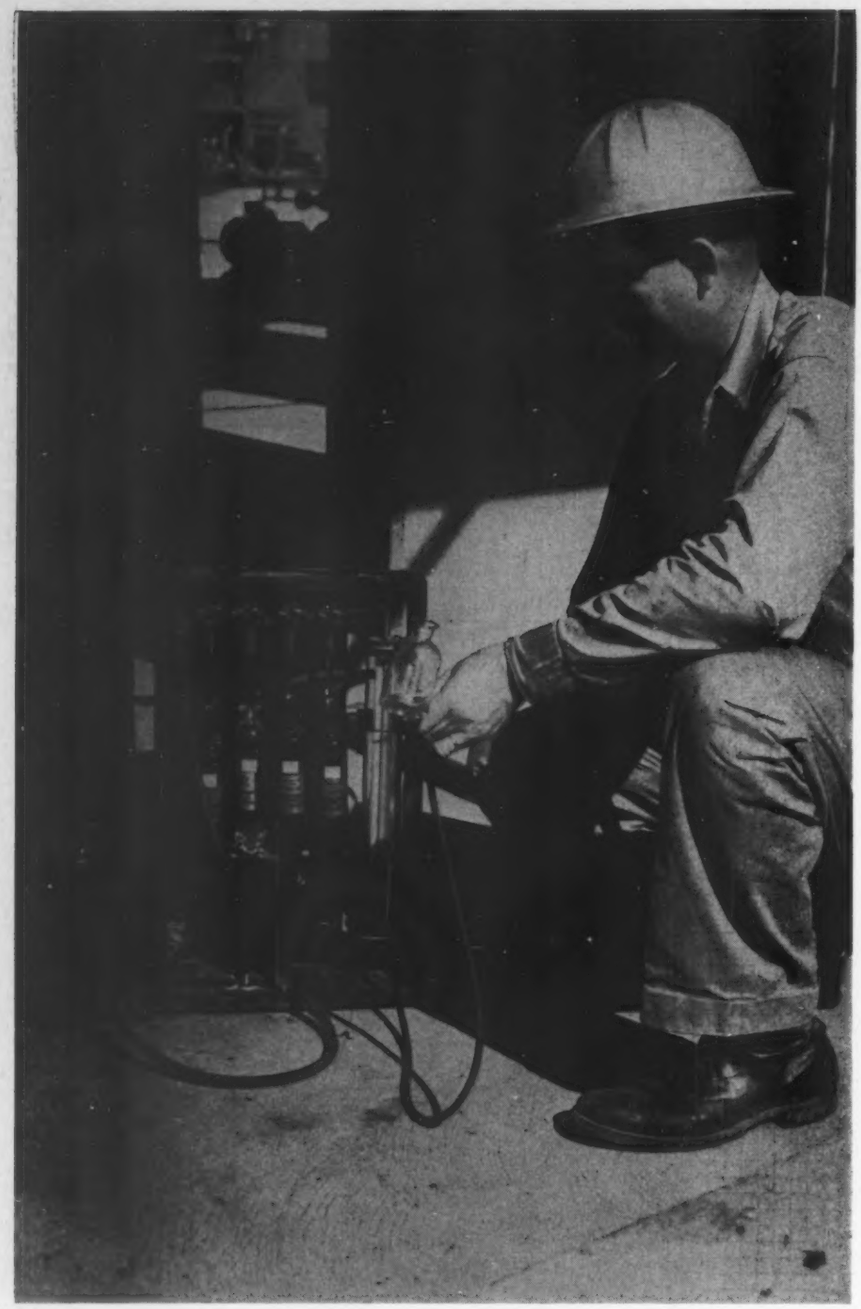

Mellon Institute - P.D.M.S.
Chemical Storage Fellowship
Vapor Pressure of Acrylonitrile
(Bureau of Mines, Dept. of Interior)
VAPOR PRESSURE lbs/sq in. abs.
TEMPERATURE °F

CHART VIII



Courtesy, Standard Oil Company of New Jersey

Testing a tank to determine its gas and oxygen content before allowing butadiene to enter it.

scribed by the Bureau of Explosives for inflammable liquids whose vapor pressure does not exceed 75 pounds at 105° F. Cylinders designated at ICC-4B-240, 100 pounds capacity, such as are in use for shipments of propane, are used for shipments of minor quantities. Tank cars ICC-105 insulated, such as are now in use for shipments of propane, have been used in the shipments of butadiene and isobutylene in large quantities.

These tank cars are prescribed by the Bureau of Explosives for inflammable liquids whose vapor pressure is in excess of 75 pounds and less than 225 pounds at 130° F. The tank cars of both classes ICC 104A and 105 have a capacity of 10,000 gallons. The 104A cars are of either riveted or welded construction.

Interstate shipments of styrene and acrylonitrile will come under the same ICC regulations as are prescribed for inflammable liquids of similar vapor pressures and inflammable characteristics.

As far as we have been able to learn the Interstate Commerce Commission has not as yet published specific data to cover tank car and other container shipments of styrene or acrylonitrile. It is believed that tank cars Class ICC 104 or ARA-IV will be used. These cars are provided with insulated shells with a minimum of two inches of insulation. The cars are not equipped with heating coils. The small container (5 gal.) will probably be ICC 17E STC. It will be advisable and in the interest of safety to seal off all shipping containers of styrene or acrylonitrile with an inert gas such as dry natural gas or nitrogen. The temperature of loading should be 70° F. or less.

Summary

1. Recommendations have been made for the storage, shipping, and handling of butadiene, isobutylene, styrene and acrylonitrile — the four most currently used chemicals in the synthetic rubber industry.

2. The bases for the recommendations have been as follows: (a) results of studies of the physical, chemical, and physiological properties of the four chemicals; (b) results of an investigation of the actual storage of the chemicals, under several different conditions, in mild-steel container, i.e., the effect of chemicals on container material and of container material on the stored substances; (c) results of economic studies of the factors involved: (1) storage temperature and corresponding working pressures; (2) storage capacities, range 100 to 700 tons; (3) five general types of containers; and (4) investment, operating, and other cost data.

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[15] Beilstein's "Handbuch," **1**, 207 (1918).

Special Purpose Synthetic Rubbers; Their Development and Applications

F. M. ANDREWS, Hycar Chemical Company

TO MANY Americans the success of the synthetic-rubber industry will depend upon its ability to develop readily accessible replacements for the rubber tires they tearfully observe wearing away on their automobiles. A belief that the industry's sole concern is the production of tires is quite natural; with the automobile playing such an important part in our way of life, one would expect that any rubber substitute should be judged by its ability to alleviate the present tire situation. Such, however, is not the case, for whether or not the often repeated question, "Will synthetic rubber tires be as good as those made from natural rubber?" is answered positively, the fact remains that for special purposes synthetic rubber has already justified its development and has established itself as a material worthy of merit. If natural rubber were to return tomorrow, we would discover that in many applications it had been replaced by a superior substance, moreover, that the use of the substitute had resulted in the successful manufacture of countless articles that could not have been produced from the natural product. We would realize that special-purpose synthetic rubbers had made possible an entirely new field of rubber manufacturing, a field that would continue to develop and prosper in its own name long after the need for a rubber substitute was present.

The quest for a rubber substitute is by no means a recently conceived activity. The history of the search for a man-made rubber dates back almost to the time when natural rubber became commercially profitable and follows a long and checkered trail. The price and availability of the crude material has had a large influence on the intensity of synthetic-rubber research. Whenever the price of natural rubber rose, interest in substitutes was stimulated; whenever it fell, this interest waned. Understanding our predicament today, and remembering the experience of Germany during the last war, we are well aware of the part the availability of natural rubber has played as an incentive in this research.

The early scientists, realizing that it was necessary to know the chemical composition of any material before it could be duplicated, sought to understand just what rubber was. They never did obtain the answer to their problem and to this day the exact chemical composition of rubber has not been fully determined. As early as 1833 scientists in England and France were seeking the solution by means of destructive distillation, yet no notable achievements took place until 1860 when Williams separated isoprene (methyl butadiene) from among the products of this distillation. It is interesting to note that, although this was one of the earliest developments of rubber research, isoprene, or some of its close relatives in the butadiene family has been the basis of almost every rubber substitute ever made. In 1879 a Frenchman by the name of Bouchardat discovered that from isoprene he could prepare a substance having "the elasticity and other properties of rubber itself." The problem of synthetic rubber then resolved itself into one of producing isoprene from a source other than rubber, and it was accomplished in 1882 when Tilden made it from turpentine. In 1892 he reported that a sample of his turpentine-derived isoprene had spontaneously polymerized to rubber. Although he failed to learn the secret of speeding up the process it is generally acknowledged that he was the first to prepare a synthetic rubber from a non-rubber source. In 1910, Harries, in Germany, and Matthews and Strange, in England, discovered that sodium would act as a catalyst for the "change" in isoprene, and the manufacture of isoprene rubber was started on a small scale in Germany. Shortly thereafter methyl isoprene (dimethyl butadiene—a methyl derivative of isoprene) was turned to as a substitute, for isoprene was difficult to make. The scarcity of rubber in Germany during the World War made it necessary that some rubber substitute be found. The development of two types of the methyl isoprene rubber followed and were called methyl rubber. One was hard, and found use for battery boxes, battery separators, etc. The other was soft and was used for solid tires. Proof of the inadequacy of this type of rubber was revealed by the fact that its production was dropped immediately after the signing of the armistice. The shortcomings were due more to the lack of compounding knowledge than to a fault of the synthetic itself. Had the Germans employed carbon blacks as reinforcing pigments their rubber probably would have been fairly satisfactory.

Impetus to Search

About 1925 certain countries decided to become self-sufficient in basic commodities. This fact, together with a rise in the price of crude rubber, provided impetus for further synthetic rubber development. When prices fell in 1926 much of the work was stopped, but many of the rubber substitutes on the market today received their start during that period. In the United States chemists ceased trying to duplicate the chemical composition of rubber. They began to feel the solution lay in developing materials having some of the properties of rubber regardless of their consistencies. In 1926 Semon plasticized poly

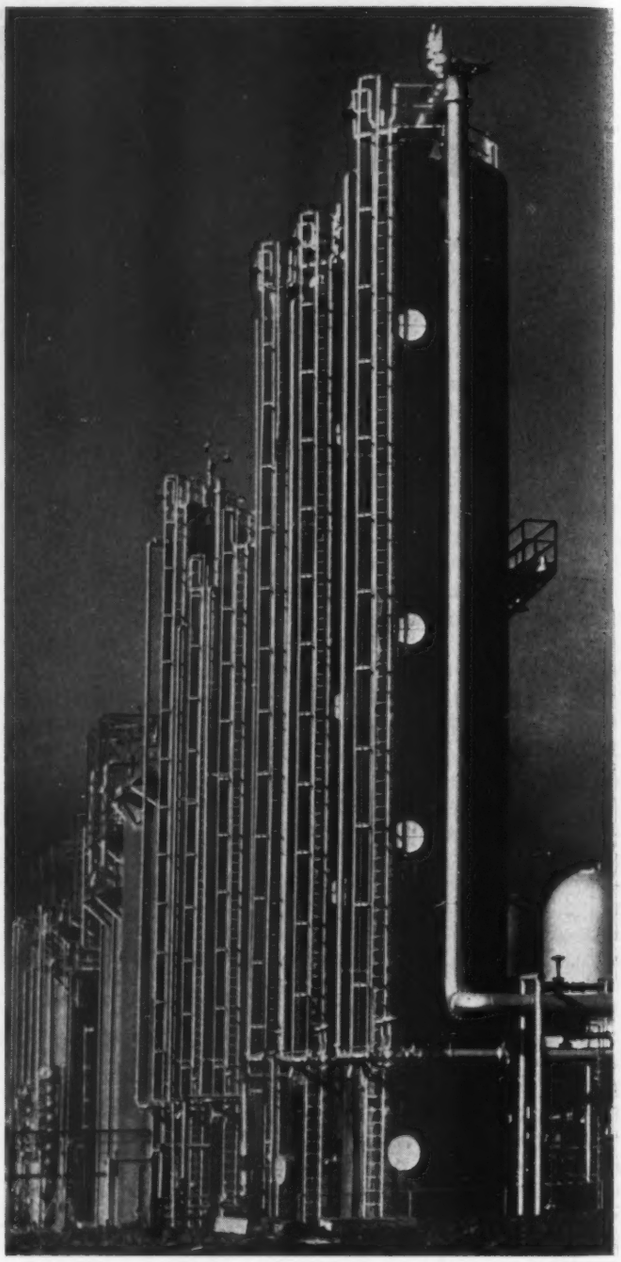
vinyl chloride and obtained a rubber-like material which we now know as "Koroseal," valuable for its fire-resisting and corrosive-resisting properties. That same year Patrick reacted ethylene dichloride and sodium poly sulfide and obtained a substance which has served as a basis for "Thiokol," a material highly useful for making hose, as it is resistant to aromatic oil and lacquer solvents. In the early 1930's in Germany it was discovered that isobutene could be polymerized. The resultant material now made and sold in this country under the name "Vistanex," is useful for many purposes, but its use arises from the fact that it is chemically non-reactive, and for that very reason, it cannot be used in most rubber processes since it remains permanently thermoplastic and is incapable of vulcanization. In 1931, E. I. du Pont de Nemours & Company, working on the earlier discoveries of Father Nieuwland, found that by polymerizing acetylene, they could obtain vinyl acetylene. When reacted with hydrochloric acid this yielded chloroprene, which upon standing polymerized to a rubber-like material now known as "neoprene." It has received extensive use in stocks which are to resist oil, sunlight or ozone.

"Tire Rubber" Developed

As early as 1912 it had been discovered that both isoprene and butadiene could be emulsified in water and that this emulsion would polymerize to a latex. Later, it was discovered that when isoprene and dimethyl butadiene were polymerized together, a substance of better quality was obtained. The discovery in 1934 of other comonomers of butadiene was an outgrowth of this earlier work. With styrene as a comonomer, a "tire rubber" was developed, which the Germans called "Buna S." With acrylonitrile an oil-resistant material, which was called "Buna-N" and later renamed "Perbunan," resulted. In 1935 the commercial production of Buna ("Bu" from the first two letters in butadiene and "Na" from the first two letters of natrium, the Latin word for sodium) synthetic rubbers by Germany was announced, and in 1938 the German army rolled into Austria on tires made from these materials. Practical synthetic rubber had become a reality. Shortly thereafter, Hycar Chemical Company (owned jointly by The B. F. Goodrich Company and Phillips Petroleum Company), Goodyear Tire & Rubber Company, Firestone Tire & Rubber Company and Standard Oil Company (New Jersey) announced new variations of these butadiene-derived synthetic rubbers.

"Synthetic Rubber" Broad Term

To insist upon a strict definition of the term "synthetic rubber"—that is, a substance resulting from chemical synthesis which is similar to natural rubber in chemical composition, physical properties, and in resistance to chemical reagents and mechanical forces—is to close the door on the use of this term in connection with all the synthetic elastomers which have been produced to date. However, we have come to use the term "synthetic rubber" for any material which possesses rubber-like qualities regardless of the chemical structure of that material. Many chemists still insist upon more exact terms, but the rubber substitutes have become so generally considered synthetic rubbers that it is doubtful whether they shall ever be called by any other name. Thus, we know synthetic rubber as all rubber-like materials which have a fair degree of elasticity and retraction, and



From Refining Plants to ⟶

are used as substitutes for natural rubber in many manufacturing operations.

The history of the development of rubber substitutes shows clearly the trend toward "tailor-made" or special-purpose synthetics rather than toward a general replacement for natural rubber. Understanding that, it is easier to weigh the merits of the man-made rubber against those of the natural material. For although no one rubber substitute contains all of the properties of crude rubber, the use of special-purpose synthetic rubbers will enable the rubber compounder to duplicate practically all of the properties of natural rubber and in many cases surpass them.

Natural-rubber compounds are somewhat superior in elasticity, rebound and extensibility and this is also the case with regard to low energy loss and low heat generation through hysteresis. However, for resistance to the action of solvents, oil, fats, and

greases, resistance to deterioration by heat and to the action of air and ozone, for resistance to aging in storage and sunlight and to many corrosive chemicals, for low water absorption, and low permeability to gases, synthetic materials are supreme, and it is for applications involving these latter properties that they have displaced natural rubber and have established a field for themselves.

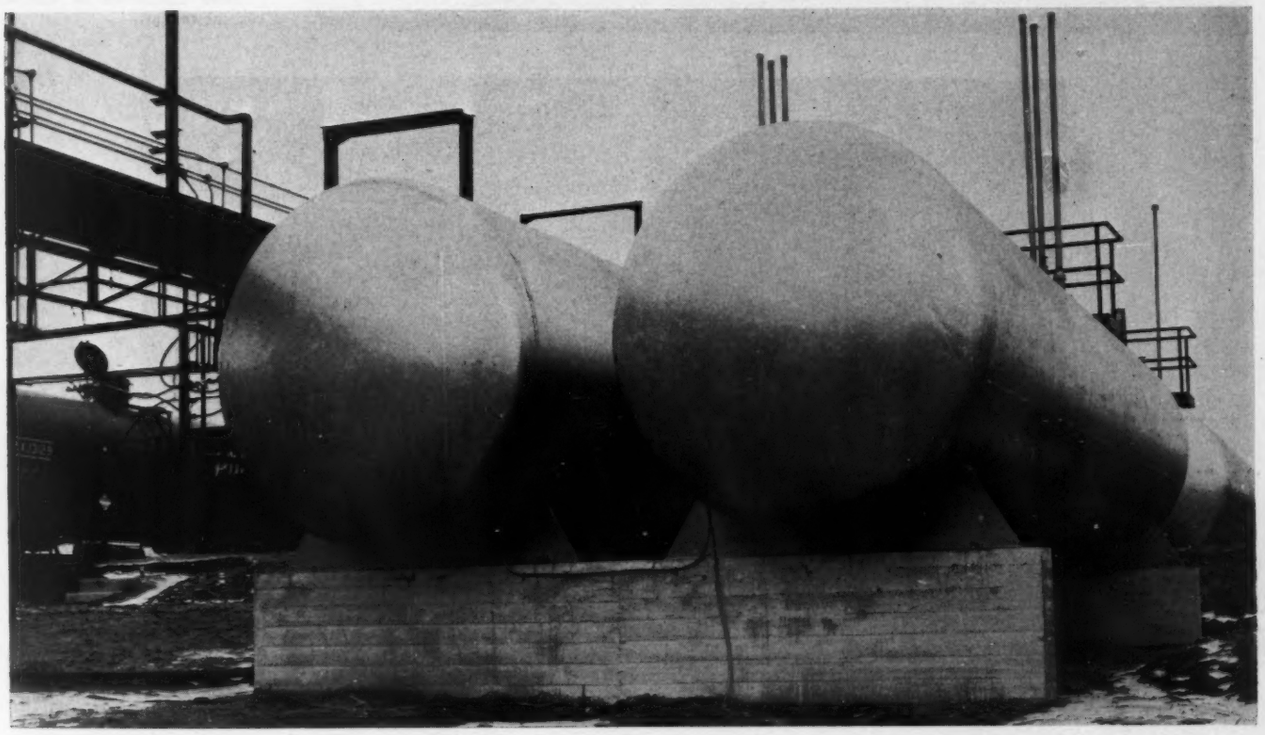
Special Applications

Hycar Chemical Company's Hycar OR-15, is an excellent example of a special-purpose synthetic rubber. For uses in which natural rubber would fail miserably, this material can itself justify synthetic rubber development. Designed principally for oil-resistant applications, it is outstanding in its resistance to all products derived from petroleum, vegetable oils, fats, and paint and ink driers. Ordinary Hycar compounds have excellent heat resistance, while special compounds designed specifically for heat resistance are exceptional. Under normal conditions its abrasion resistance is about 30 per cent better than natural rubber, while at high temperatures and in the presence of oils, Hycar is considerably superior. Its compounds have greater resistance to oxidation and to cracking when exposed to light or ozone under tension than have compounds of natural rubber. "Hard rubber" compounds of this rubber substitute, known as "Ebonars," reveal an outstanding advantage over natural rubber ebonites in their higher softening temperatures. Softening points of about 300° F. or about 100 degrees higher than for natural rubber, are readily obtainable. Thus, it will be easily understood that war industries are utilizing either directly or indirectly, all the Hycar OR-15 that is being produced. At the present time about 80 per cent of all Hycar products are going directly into war use and the remainder is being employed for purposes very closely associated with the war effort. For example, these products are finding use in equipment for the production, refining and distribution of petroleum. The many varied uses in both these fields are constantly changing, so any list, however complete one day would probably be outmoded the next. Some of its wartime uses are: Bullet-sealing fuel tanks, bullet-sealing hose, crash rafts, aviators clothing, gas-resisting fabrics, and a multitude of similar types of applications.

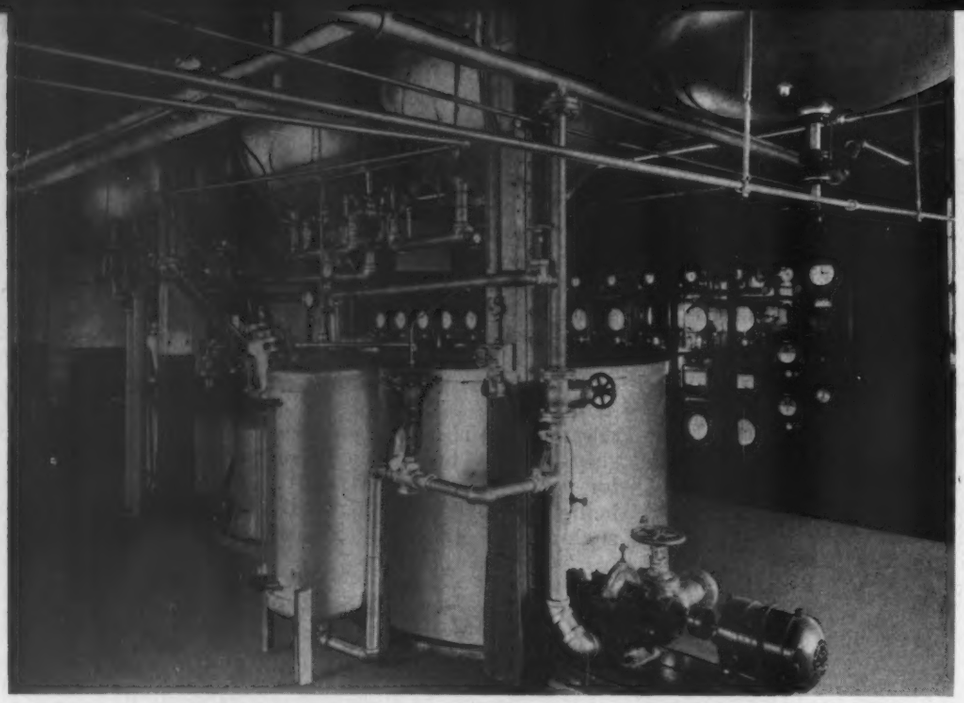
Synthetic rubbers highly resistant to the action of sunlight are finding use in airplane deicers, and in oil-and-light-resistant fabrics for ballons and airships. Those highly flame resistant are being used for wire covering going into war ships. Another is being employed for electrical insulation applications such as wire and cable covering and similar uses.

After the War

The lists of wartime uses furnish merely a prelude to the countless applications of these materials that are to follow after the war. Many of these have already been developed and need only to be put into production. Others require only the "finishing touches" before they can be utilized. With the resumption of normal activities much of the development and research now directed along war uses will be put into play to promote the peacetime utilization of these new materials, and it would be difficult, if not impossible, even to estimate the many varied synthetic-rubber products that will then result. For one thing, at the present time approximately 25 per cent of the rubber content of an automobile is synthetic. It would not be very hazardous to predict that with the possible exception of the tires, 100 per cent of rubber in automobiles will be of the synthetic variety. This will include all the rubber seals, body bumpers or insulators and all the flexible oil and gas lines. Yet the automotive industry will merely scratch the surface of synthetic rubber applications.

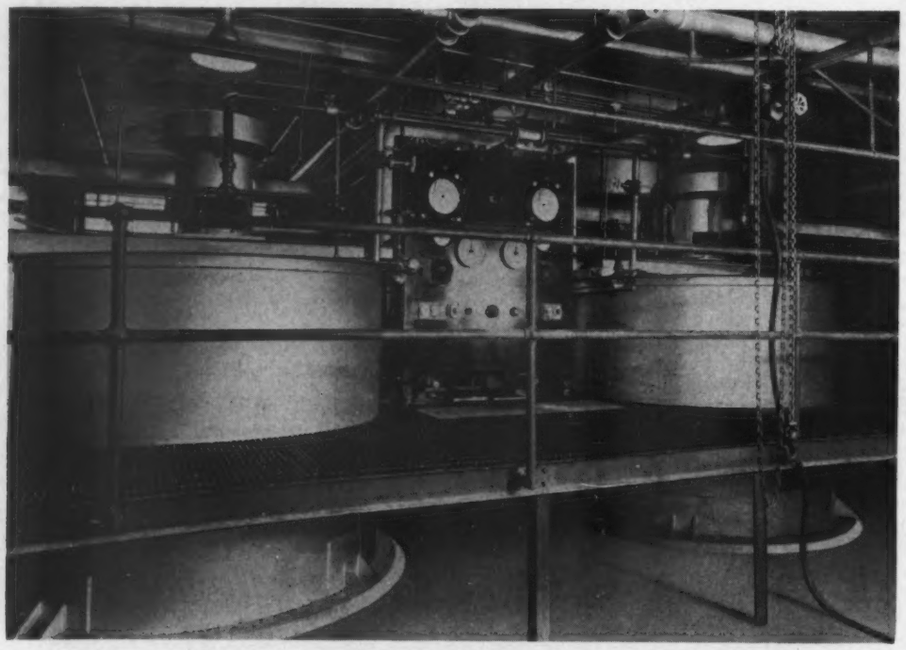


Butadiene Storage Tanks to——→



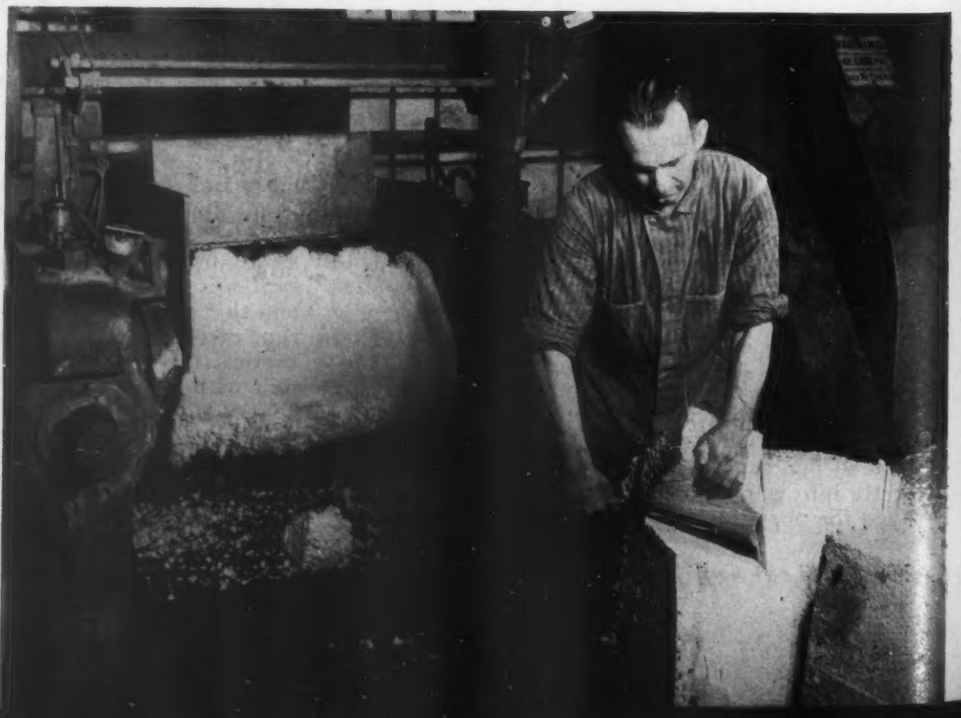
POLYMERIZATION UNITS

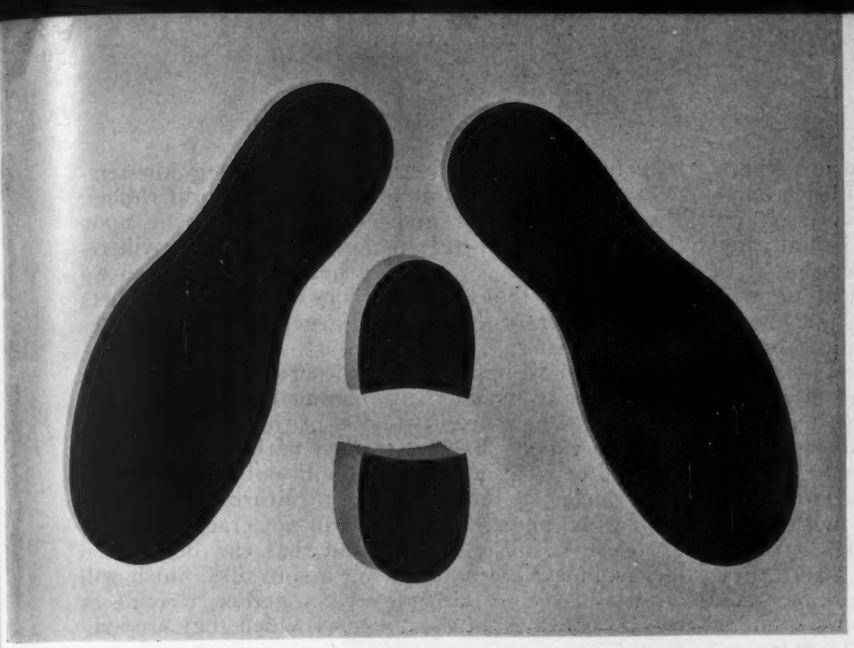
Special soap solution is used to emulsify Butadiene and other ingredients. This mixture is then polymerized under controlled conditions in Reactors as shown, left.

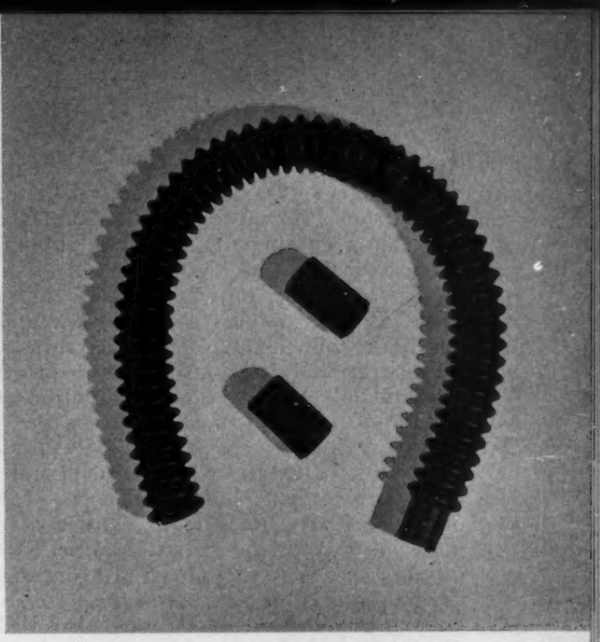


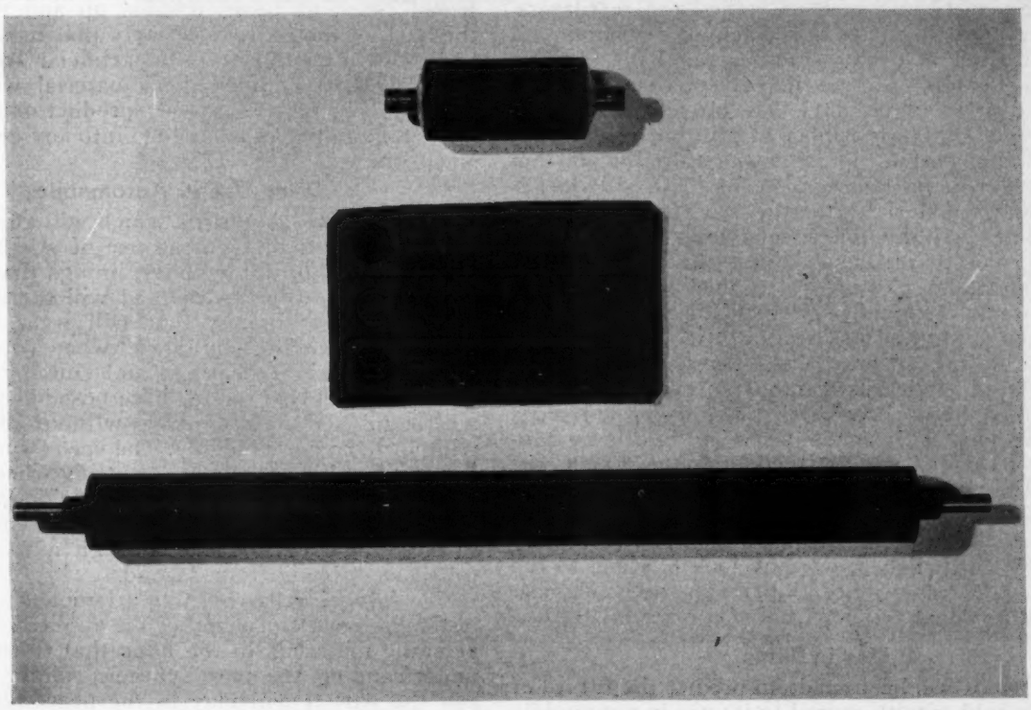
The Synthetic Latex is next coagulated in tanks, above.

Curds of rubber are poured into forms where they solidify into blocks weighing 110 pounds, which are cut and placed in wash mills. After removal from the wash mill sheeted Hycar is dried and packed for shipment to rubber processors.

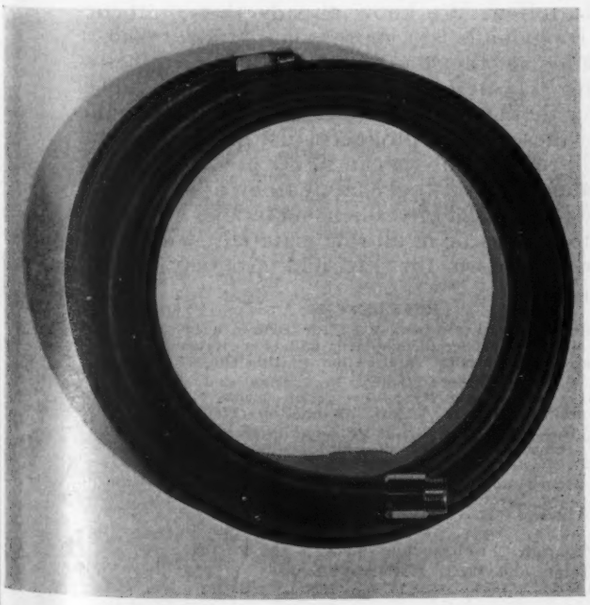


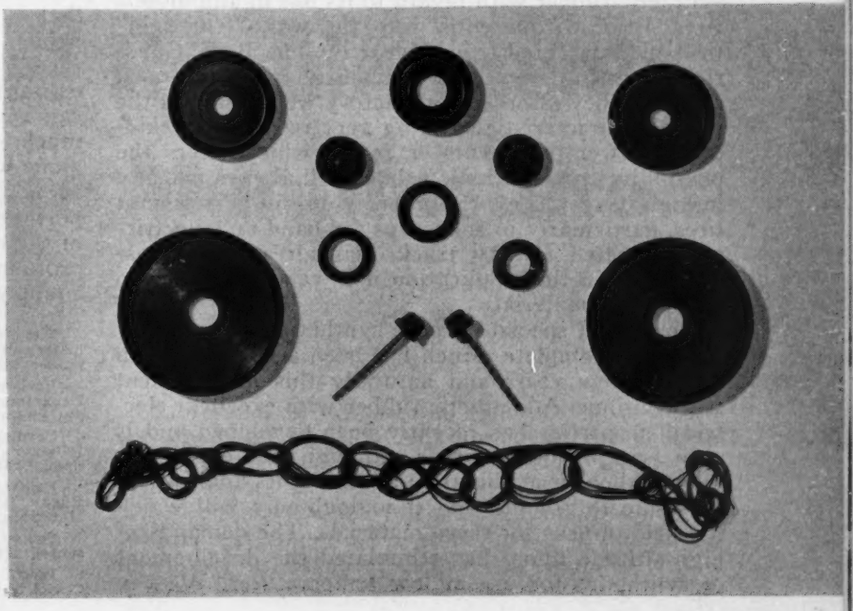






A few typical products being manufactured from Hycar





Added to this list will be all wire insulation where oil resistance is a factor, such as in cables around transformers, in motor ignition-cable coverings and in welding equipment. Synthetic rubber has already been extensively used for hoses of all sorts but it is likely that even in this field its applications will grow. We can expect a huge growth in the use of synthetic rubber for oil and gas ship-loading hoses, filling-station hose, for paint and lacquer hose, for refinery bulk-loading hose, oil suction and discharge hose and a myriad of applications in which natural rubber would prove entirely unsatisfactory. The petroleum industry will avail itself not only of synthetic-rubber hose but of all sorts of packings and oil seals. Coats made from cloth coated with these materials will be a constant comfort to men working in laboratories or in industrial processes where they are liable to come in contact with gas, acid, or other poisonous substances. Fabrics also will be used in diaphragm materials such as valves and regulators. Coverings will be made for machinery wherein oil has been used to prohibit rusting, and for packing and export shipping to guard against salt-water damage. The printing industry has already discovered the value of synthetic rubber in printing rollers that are very resistant to abrasion and to paint and ink driers and will no doubt come in for a still larger share of this material after the war. Industrial conveyor belts will be made capable of transporting dustless coal and other substances that would quickly deteriorate belts of natural rubber. Synthetic rubber belts will also find use for drying powder-carrying solvents. Oil and gas station attendants, men in packing houses or any place where fats, oils or greases would quickly wear out an ordinary rubber sole, will discover their synthetic-rubber-soled shoes providing long and excellent service. Synthetic rubber will be called upon to make sponge which will provide insulation where oil and heat resistance is essential. The superiority of synthetic hard rubber has already been pointed out; since it can be readily machined and polished, we may look forward to the production of many exceptionally attractive household and personal articles from this material.

Use in Tires

No attempt has been made to predict the future of synthetic rubber with regard to its use in automobile tires. Prior to our entry into the war, "Ameripol" tires manufactured from Hycar by The B. F. Goodrich Company were sold competitively on the open market. They afforded satisfactory wear and had the unique characteristic of being very resistant to skidding on wet pavements—a factor which offers the possibility that synthetic rubber will always find use in high quality tires. However, its use in oil-resistant tires, particularly in solid tires for hand and electrically operated factory trucks has already been assured, for in this application it is vastly superior to the natural material.

The list of special purpose synthetic rubbers is by no means complete. Much has been accomplished in the last few years and naturally this development will continue. A synthetic rubber with excellent electrical properties has recently been developed and is now being manufactured; although not enough is known about it at this time to review its application, it is safe to assume that it undoubtedly will widen the field of uses for these materials. The demands of high-altitude flying has stimulated the development of synthetics for use at low temperatures. We can look forward to synthetic rubbers having low-temperature flexibilities far in excess of natural rubber. Every development and every improvement upon those materials already being manufactured, will result in new ways to utilize these substances, so we might expect that the processing of synthetic rubbers will constantly become a larger part of rubber manufacturing.

It would be impossible to describe completely the many uses to which these man-made substances will be put, but here are just a few of the things we may come to expect. Fabrics treated with synthetic rubber will be used in the manufacture of awnings, window shades, porch and lawn furniture that will be absolutely water proof, that will not crack or rot by exposure to the elements, and that can be cleaned in gasoline. Raincoats having a soft silky finish will be produced and will not stick together, wrinkle or crack regardless of the abuse to which they are subjected (such as being wadded up and thrown into the back of the car). It is likely that most industrial leather will be replaced by artificial leather made from synthetic rubber. This material will have all the qualities of the present product plus the very important ability to be molded into any desired shape and form.

Wide Use in Automobiles

Industrial developments which will affect the general public will involve the use of synthetic-rubber brake linings for automobiles, linings that will withstand higher temperatures and will therefore be far more effective; linings that will wear better, last longer, and not "let you down" when you need them most. Automobile bearings and clutch facings that can operate in oil are a definite possibility. They too will stand high temperatures without ill effect and will not burn out suddenly. The use of synthetic rubber as a bond in abrasive and cutting wheels will promote new achievements in that field. We will see cutting wheels, working in oil or an oil emulsion, bite through tungsten, or cut through a two-inch cold rolled steel bar in four seconds.

The foregoing has been an attempt to touch merely the high spots of many of the applications of these versatile materials in the hope that it will assist in understanding the part syntheic rubber now plays and the part it will play in the peacetime economy that is to follow. We know already that synthetic-rubber compounds are more than "rubber substitutes," and that they can stand on their own merits, exhibiting countless qualities which natural rubber can never duplicate. We know that the future holds much for these unique products. Just how much, time alone will reveal. But we can safely predict that synthetic rubber will not only prove to be of utmost importance in the field of resilient materials, but as one of the most versatile of all raw materials, will have a profound effect on the life and economy of our country.

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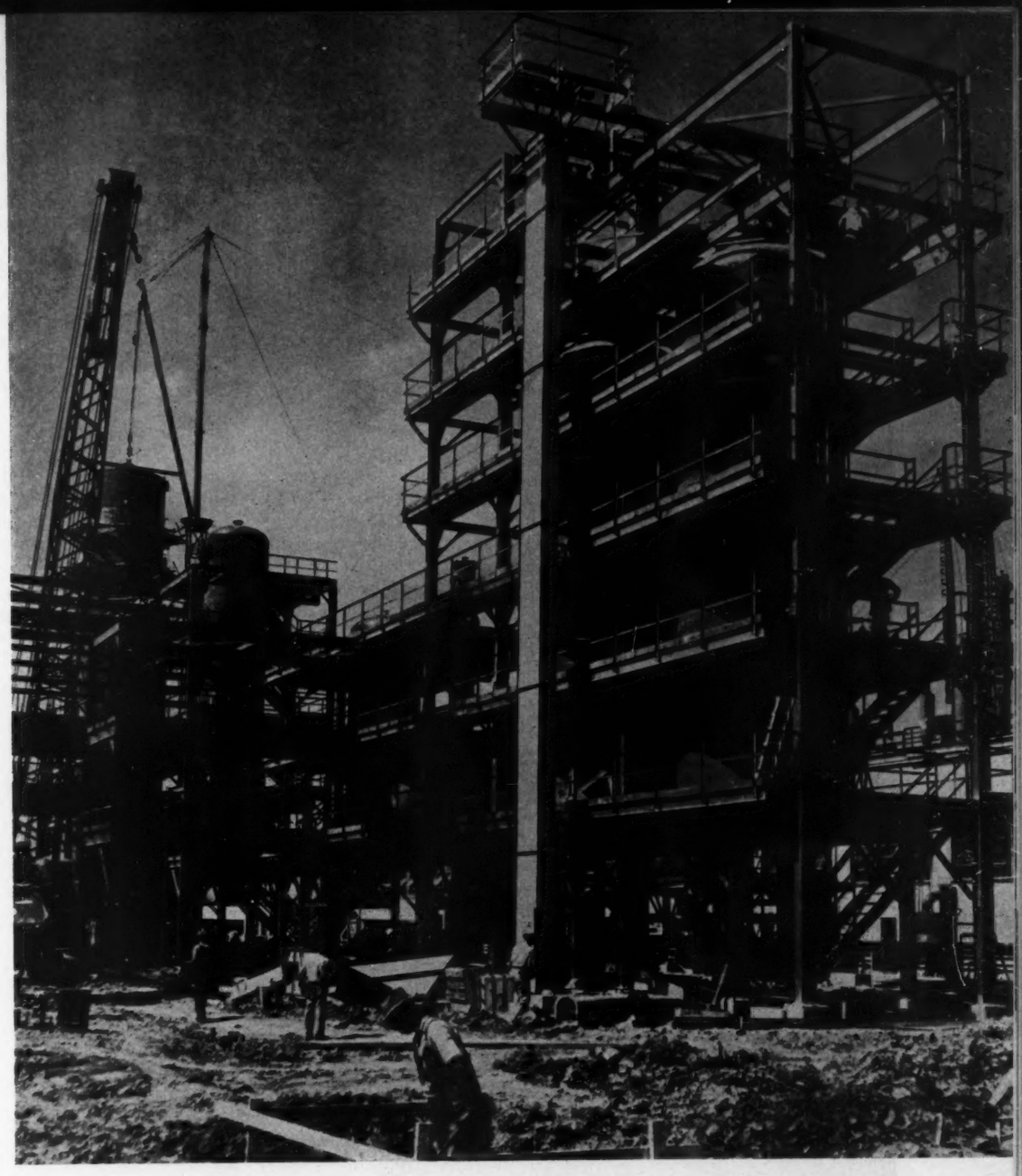
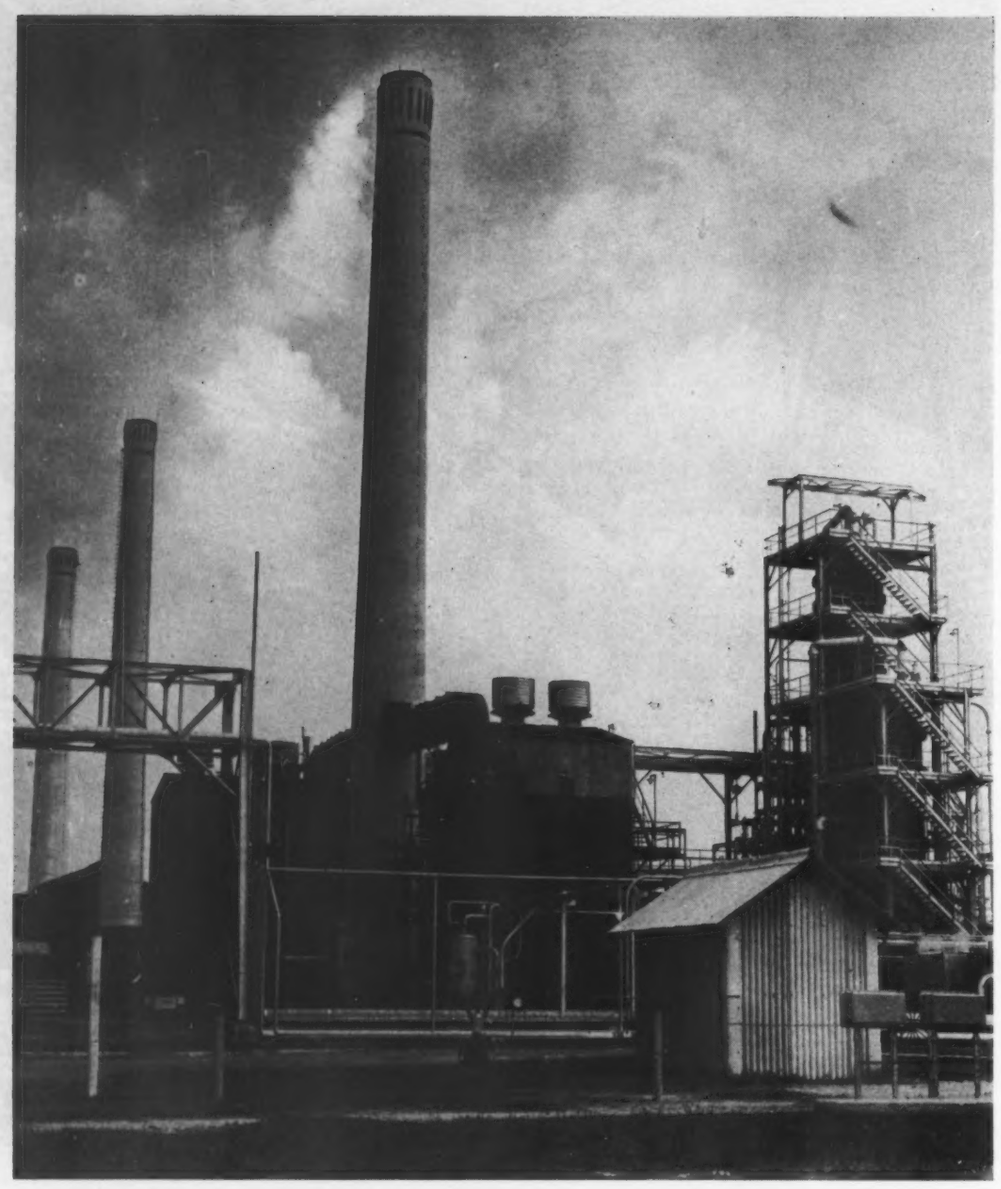


Metallurgical Requirements In Butadiene Manufacture

J. V. HIGHTOWER, Staff Writer

WHAT metals to use in the manufacture of butadiene is a problem that in general is governed by the same factors controlling the use of such materials in the familiar fractionating and cracking units in the refinery. At present, however, there is one important difference, the scarcity of materials, which is changing former practices with the aim of reducing the use of metals in the critical category.

To summarize the factors that normally control the use of alloys in butadiene equipment, the principal ones are: presence or absence of corrosive agents in charge stocks, temperatures and pressures of operation, corrosiveness of refrigerants, and possible injurious catalytic effect of some metals on butadiene. Obviously if butadiene happens to be made from a naphtha or other charge stock containing a high



FURNACES

percentage of sulphur compounds, extensive use of alloys would be called for, although there is little prospect that such high-sulphur stocks will have to be or could be employed. Maximum temperatures of well over 1000° F. are developed in most of the butadiene processes and will require some alloy steels to resist oxidation. On the other hand, because butadiene manufacture is characterized by low-pressure operation (below 100 pounds per square inch, gauge), the high-temperature operation does not create the serious problem of creep in tubes that demands considerable alloy in conventional high-pressure cracking.

Where Alloys Used

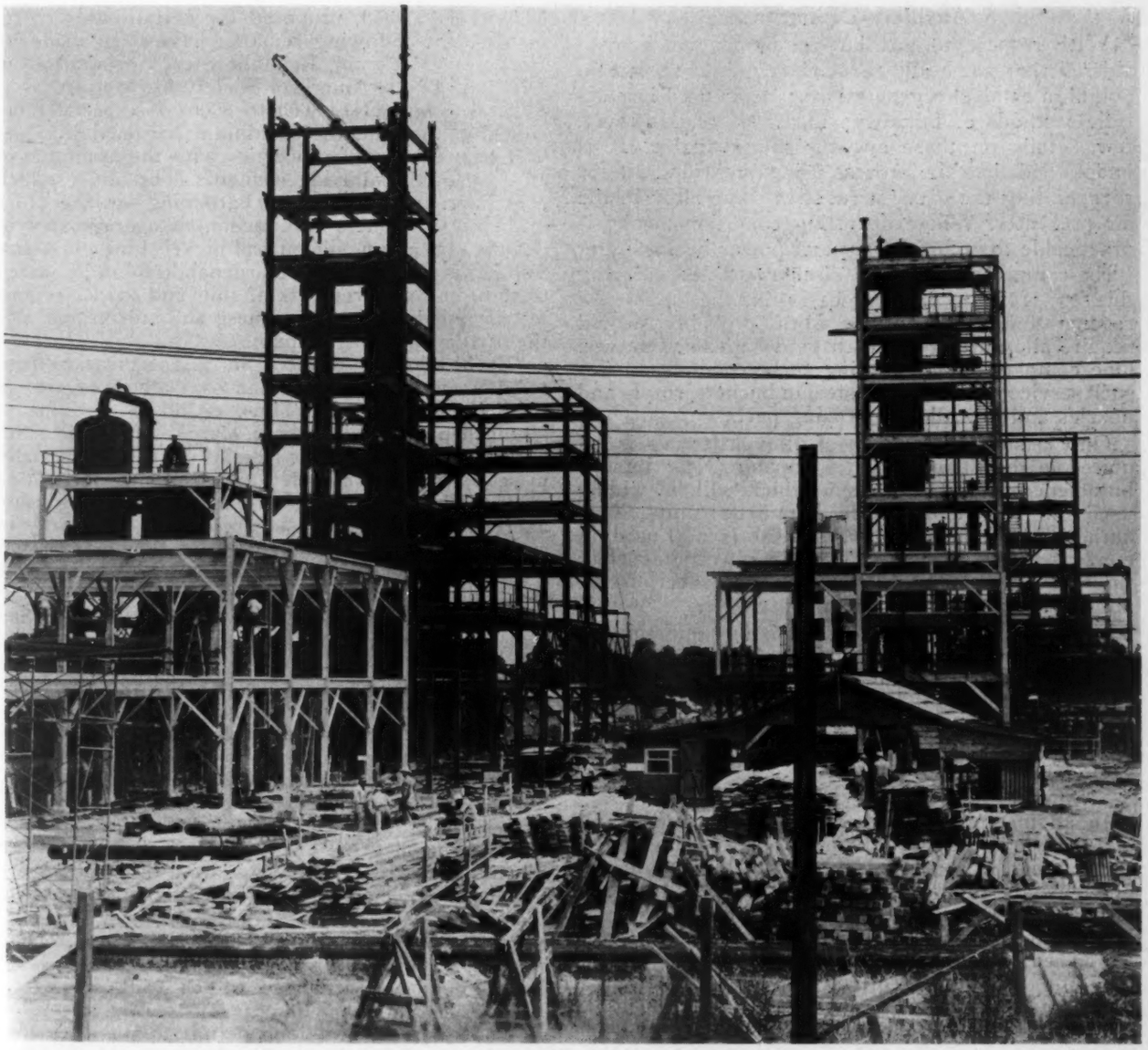
In general, the principal use of alloy steels is centered in the hotter sections of furnaces where temperatures are higher than 1000° F. Such temperatures will be found in furnaces of equipment to make butadiene by various thermal-cracking methods, and this equipment is being utilized widely in the "quick butadiene" program of OPC. One type of plant-conversion process is the making of such changes in high-pressure naphtha-cracking units as will permit operation at considerably higher temperature and markedly reduced pressure. The charge stock is rapidly heated in a tube furnace to temperatures in the range of 1100-1300° F., and at the same time a stream of normally gaseous material, such as hydrocarbon gas, air, flue gas or steam, is independently heated to temperatures of around 1400-1500° F. The hot charge stock and gas are then combined to raise the temperature of the mixture to the point where the production of butadiene will occur.

It is apparent that those portions of the furnace tubes which reach the above temperatures should consist of the alloy steels ordinarily used in extreme-high-temperature operation. This applies to tubes for heating both naphtha and gas. Obviously, heat-resisting alloy is needed in the transfer lines carrying the furnace effluent to the reaction chamber or quench point. Furthermore, the tube hangers which attain the high temperatures should be of alloy material. The same is true of structural castings, instrument connections and valves and fittings. Fortunately, it will happen in numerous instances of plant conversion that sufficient alloy materials already exist for butadiene operation.

In reactor chambers into which the effluent materials from the furnace enter, alloy steels may or may not be used. The Petroleum Conversion Corporation, in its system of converting thermal naphtha-cracking units to butadiene operation by use of low pressures and high temperatures, specifies a carbon-steel reactor with an internal lining of refractory. The Houdry Process Corporation finds that its catalytic reactor cases, used in the conversion of normal butane feed to butadiene by the Houdry butadiene process, may be satisfactorily made of carbon steel if an internal lining of fire brick is provided in them. In these cases the only point at which alloy steel is employed is the horizontal supporting plate for the catalyst bed. Valves, piping and fittings used in high-temperature-reactor service, would ordinarily be of heat-resisting alloys also.

Whether alloys would be used in the fractionation systems of butadiene units depends almost entirely on the presence or absence of severely corrosive agents, such as sulphur compounds and acids, in the gases and liquids handled. Temperatures in the fractionation systems are below 1000° F. and therefore do not of themselves call for alloy construction. It is not anticipated that alloys will figure importantly here, because at least in the instance of catalytic processes making butadiene from C_4 feed stocks, such feeds will be freed of agents which poison the catalyst. In the thermal processes, using heavy naphtha feed stocks, it is considered that an ample supply of low-sulphur naphthas will be available.

As for possible polymerizing effects on butadiene of metals used in fractionating systems, some as yet incomplete studies being made of the effect of various metals on butadiene indicate that polymerization from this source is negligible or non-existent, and that butadiene is as non-corrosive as other pure petroleum hydrocarbons. Several engineers declare that no trouble along these lines is expected. This would mean that metals in tower shells, drums, coolers and condensers would be no different from what they are in the processing of other hydrocarbons free of foreign corrosive agents. High temperatures are the chief cause of premature polymerization of



New Construction—Cracking and Distillation Equipment

TABLE 1

National Emergency Steel Specifications

(Announced by the Iron and Steel Branch of the War Production Board as possible alternates for Nickel, Chromium and Chromium-Nickel constructional alloy steels)

Des.	Carbon	Mang.	Moly.	Nickel	Chromium
NE 8024	0.22/0.28	1.00/1.30	0.10/0.20	.....	.....
NE 8124	0.22/0.28	1.30/1.60	0.25/0.35	.....	.....
NE 8233	0.30/0.36	1.30/1.60	0.10/0.20	.....	.....
NE 8245	0.42/0.49	1.30/1.60	0.10/0.20	.....	.....
NE 8339	0.35/0.42	1.30/1.60	0.20/0.30	.....	.....
NE 8442	0.38/0.45	1.30/1.60	0.30/0.40	.....	.....
NE 8447	0.43/0.50	1.30/1.60	0.30/0.40	.....	.....
NE 8547	0.43/0.50	1.30/1.60	0.40/0.60	.....	.....
NE 8620	0.18/0.23	0.70/0.95	0.15/0.25	0.40/0.60	0.40/0.60
NE 8630	0.27/0.33	0.70/0.95	0.15/0.25	0.40/0.60	0.40/0.60
NE 8724	0.22/0.28	0.70/0.95	0.20/0.30	0.40/0.60	0.40/0.60
NE 8739	0.35/0.42	0.75/1.00	0.20/0.30	0.40/0.60	0.40/0.60
NE 8744	0.40/0.47	0.75/1.00	0.20/0.30	0.40/0.60	0.40/0.60
NE 8749	0.45/0.52	0.75/1.00	0.20/0.30	0.40/0.60	0.40/0.60
NE 8817	0.15/0.20	0.70/0.95	0.30/0.40	0.40/0.60	0.40/0.60
NE 8949	0.45/0.52	1.00/1.30	0.30/0.40	0.40/0.60	0.40/0.60

Note: The following additional element specifications apply to all the basic open hearth steel shown above: Phosphorus 0.040% max.; Sulfur 0.40% max.; Silicon 0.20/0.35%.

butadiene, and this difficulty will be met by introducing inhibitors into the butadiene stream during processing.

Auxiliary Equipment

With respect to auxiliary equipment it is considered that some alloy steel is required at certain points in catalyst-regeneration systems used in catalytic methods of butadiene manufacture. However, few details on these systems are available. It is understood that one process using preheated air for regenerating the catalyst requires some alloy in the air preheater. Where operating conditions make it practicable to secure by-product power by installing turbo-compressors in the discharge lines carrying flue gases from catalyst cases in the course of regeneration, such compressors probably would require alloy fittings to withstand high temperature. One company manufacturing turbo-compressors for such service used stainless steel in buckets, rotors and nozzles and low alloy for casing parts.

Only a small proportion of alloy materials is required in the Standard Oil Company (New Jersey) butadiene-purification system which will be widely used in connection with butadiene units. One authority declares admiralty metal is not used in condensers and coolers which come into contact with the butadiene absorbent because of the effect of that absorbent on admiralty or similar alloys.

Refrigeration compressors utilizing ammonia as the refrigerant require stainless steel or other ammonia-resistant metal in the gaskets in place of copper or aluminum. As for butadiene storage tanks, it is declared generally that these may be made of ordinary carbon steel.

Substitutes Essential

In all instances, the extent to which alloys will be used where they would normally be specified must be governed in varying degree by the availability of alloy metals and by substitutions which are found practicable. Max B. Miller, head of the equipment procurement section of the refining division, OPC, has recently released some recommendations, proposed by oil and engineering concerns, for the saving of alloys. These include:

1. When using chromium and nickel for prolonging the life of equipment, design equipment for a three-year life avoiding major repairs.

2. Use standard steels in place of high-alloy special steels when operating conditions permit.

3. Use alloy overlays (applied alloy surfaces) rather than alloy throughout.

4. With regard to furnaces, limit the use of alloy steels for tube hangers only to those parts of the furnace which absolutely require alloy. Specify calorized steel in place of alloy for wall ties.

5. Reduce requirements for alloy in bolting materials by specifying other steels as far as possible on the basis of service limits on bolt temperatures instead of flow temperatures in the tubes.

6. In general, eliminate the use of steel where practicable by employing substitute materials such as concrete for supports and storage tanks and plastics for tubing. Decrease the use of valves.

An important contribution to the reduction of use of scarce alloy metals has been made by the iron and steel division of WPB in the form of specifications for possible alternates for nickel, chromium and nickel-chromium constructional alloy steels. The specifications are shown in Table 1.

Regarding properties of the steels listed from NE 8620 to NE 8949, proposed for certain uses in refineries, the following remarks have been made by Harry W. McQuaid, Republic Steel Corporation, in a bulletin of the American Society for Metals:

"This group (NE 8600 to 8900) is especially designed to provide the maximum hardenability and best combination of properties with the minimum of any one of the alloying elements. The alloys which contribute to the depth of hardening—in the order of their effectiveness—are carbon, manganese, molybdenum, chromium, silicon and nickel. Fine grain size also has its usual effect. Hardenability can be varied to meet the requirements of thin and thick sections by varying first the manganese and silicon and also the carbon and molybdenum.

"Each alloying element in a specification contributes in some way to the over-all properties of the heat treated part. Thus, nickel is of value in strengthening the iron base (ferrite) by solid solution, and it improves the general ductility, especially in sections where complete quenching is difficult to obtain. Chromium is an important hardening alloy and contributes to abrasion resistance, especially in carburized or high carbon steel. Molybdenum is important as a hardening element and increases the time available for handling in quenching. It also contributes to stability of the hardened structures when high skin temperature is developed by friction, and this makes it desirable in gear and bearing steels.

"By combining in one analysis the super-imposed effects of smaller percentages of all the above elements, we achieve a uniformity in properties almost impossible to obtain in any other way. This is because it is difficult to produce, in tonage by the usual scrap and pig process, any simpler alloy steel without the other elements occurring as residuals to a varying degree. These residuals are very detrimental, since they cause a variation in hardenability from that expected in the specified composition, and therefore cause a non-uniform product. Residual elements constitute an increasingly difficult problem as alloy scrap, segregated by composition, builds up and cannot be used in many much-wanted analyses. Thus the National Emergency chromium-nickel-molybdenum combinations permit a much broader use of scrap and will simplify the steel maker's problem of residuals."

Official Photograph, U. S. Army Air Forces

Pumping Oil Into Plane

Established Processes Make Aviation Lubricants

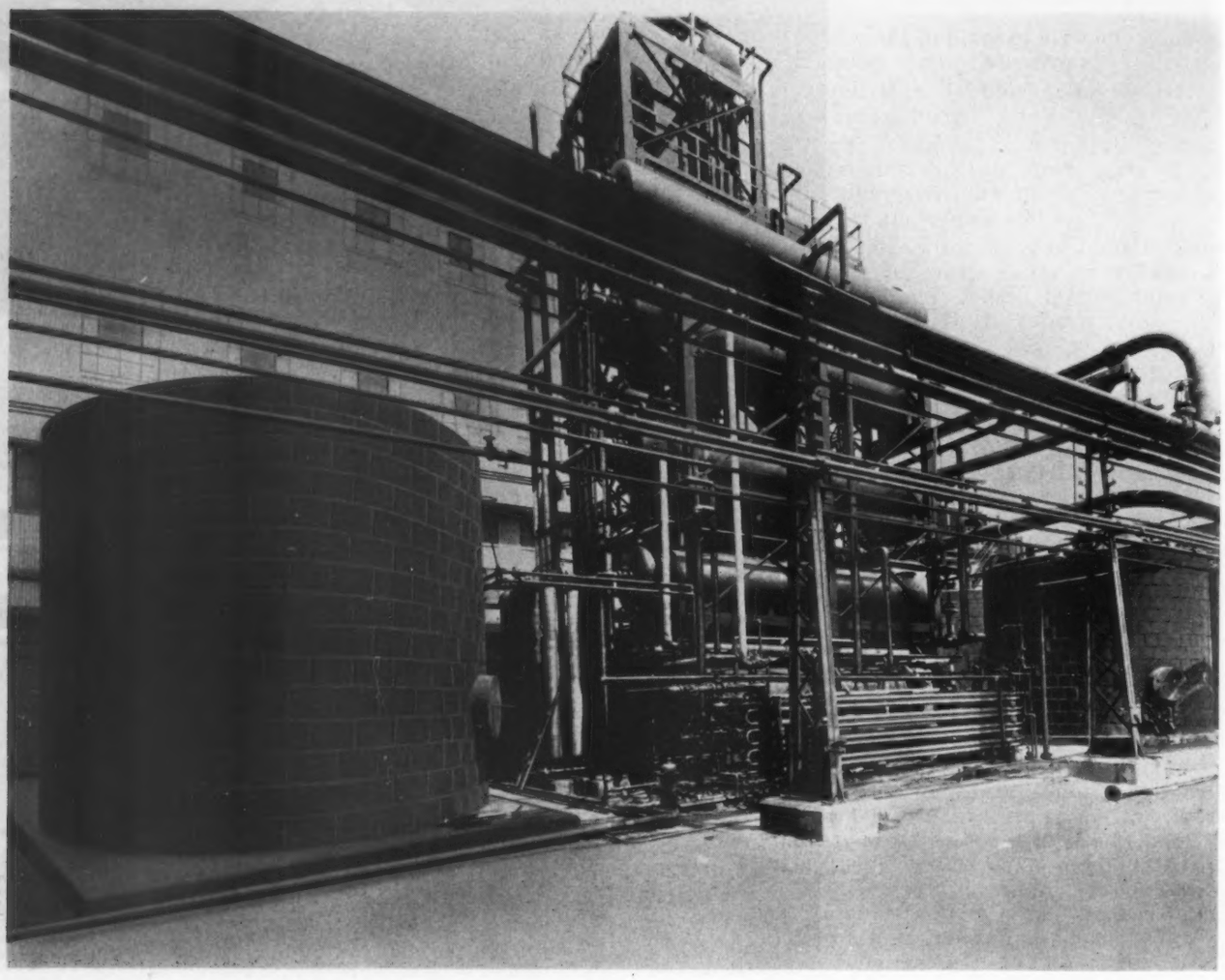
GEORGE F. FITZGERALD, Chemical Engineer

THE petroleum industry is preeminent because of its foresight in being prepared for military aviation long in advance of Pearl Harbor. As a part of that preparedness, aviation was recognized as an all-important role in modern warfare. The specialized problems of fuels and lubricants have been competently studied for years. The results have been achieved, not under wartime pressure, but with the ample time and facilities available in peace. The necessity for correct lubrication of aircraft used by our armed forces needs no arguing. It is, instead, the purpose of this paper to show how refining methods developed for peacetime production of automotive lubricants are applicable to the industry's job of meeting an unprecedented demand for superior aviation lubricants.

In this, refining faces the problem of making high-grade oils to strict specifications while reducing losses to a minimum. There is nothing especially new or astonishing in this except that the motivation is cooperation in the war program. All refiners try to keep losses down but in these times wasting a strategic material such as petroleum, especially that suitable for aviation lubricants, is next door to treason.

From Existing Equipment

Refineries which have been marketing solvent-treated, low-pour automotive oils from selected crudes can make aviation oils with their regular equipment. The principal change would be altering the degree of refining to meet aviation specifications. This does not mean that high-grade automotive oils



Courtesy, Carbide and Carbon Chemicals Corporation

Chlorex Process Unit

and aviation oils are interchangeable, but that the same manufacturing facilities may well be employed for both. The specifications for the latter are much more rigid and the viscosity ranges are totally different. Modern trends in automotive design have consistently called for oils of lower and lower viscosity until now the SAE 10 and 20 grades are the best sellers. Large-scale manufacture of aviation lubes of 100, 110, and 120 seconds at 210 will call for revision of blending ratios and distillation cuts. Neutral and bright stock demands may again reverse themselves with the present neutral shortage becoming a surplus.

Current war experience[1] has demonstrated the success of Pennsylvnia oils under actual flight conditions and has established them as the yardstick of quality. This is borne out by the estimate that 60 percent or more of the wartime demand will be filled from Pennsylvania refineries. At the current rate of increase our requirements will reach 7000 barrels per day by the end of this year with every prospect of doubling again by the end of 1943. Such an increase is only reasonable in view of our government's estimated ultimate demand of 250,000 barrels per day of aviation fuel. At the 20-to-1 average ratio of fuel-to-oil consumption used in England, 13,000 to 14,000 barrels per day of oil will not be too much.

In supplying this demand all refiners will find use for the test technological developments of the past decade. The most recent improvements naturally cannot be published in wartime but much can still be said of the application of modern methods to aviation-oil manufacture. Solvent-extraction processes for improving stability and viscosity index have become well known. By their use mixed-base oils can be upgraded to compete with those of better inherent quality. In general, extraction methods depend upon the use of a treating agent which selectively dissolves either the high- or low-grade components of the charge. Intimate mixing of oil and solvent is followed by gravity settling which affects a separation into two phases: (a) the raffinate containing the more paraffinic oil and (b) the extract solution containing the less paraffinic oils. The solvent is separately distilled from the two phases and returned to the treating system for reuse. The separation into paraffins and asphalts or naphthenes is, of course, never complete in practice. A balance is struck between quality of finished product and yield from charging stock.

Solvent Extraction

The leading extraction solvents in commercial use are: Furfural, Duo-Sol, phenol, benzol-SO_2, and Chlorex. It will be noted that solvents may be used singly or in combination. The Duo-Sol process, for example, employs[2] a cresol-phenol blend to take up the asphalts and propane to dissolve the paraffinics

and to promote separation of the two phases. By careful application of the extraction process best suited to the type of charging stock, most refiners are enabled to produce high-viscosity-index oils. In the aircraft lubricating oil specifications for Army, Navy, Pratt & Whitney, and Wright 95 is the minimum acceptable viscosity index. Without solvent extraction, Western and Coastal crude oils could not be used as supplementary sources of aviation lubricants. It must be remembered, however, that viscosity index is not the only requirement to be met. Oxidation stability is of extreme importance. It is governed by crude oil source and extraction refining and may be controlled by suitable inhibitors which will be discussed later.

Motorists who drive in sub-zero weather are familiar with winter lubricating difficulties. But even zero-temperature driving conditions are mild compared with the extremes encountered from a summertime takeoff to the constant low temperatures found at high altitudes. Airplanes, especially fighting craft, must operate smoothly under all changes of temperature and altitude. Oil failure is much more serious than fuel failure. The engine lubricant must be capable of maintaining a continuous film between moving parts to prevent wear and at the same time provide cooling of heated parts. In addition it must permit rapid cold-starting.

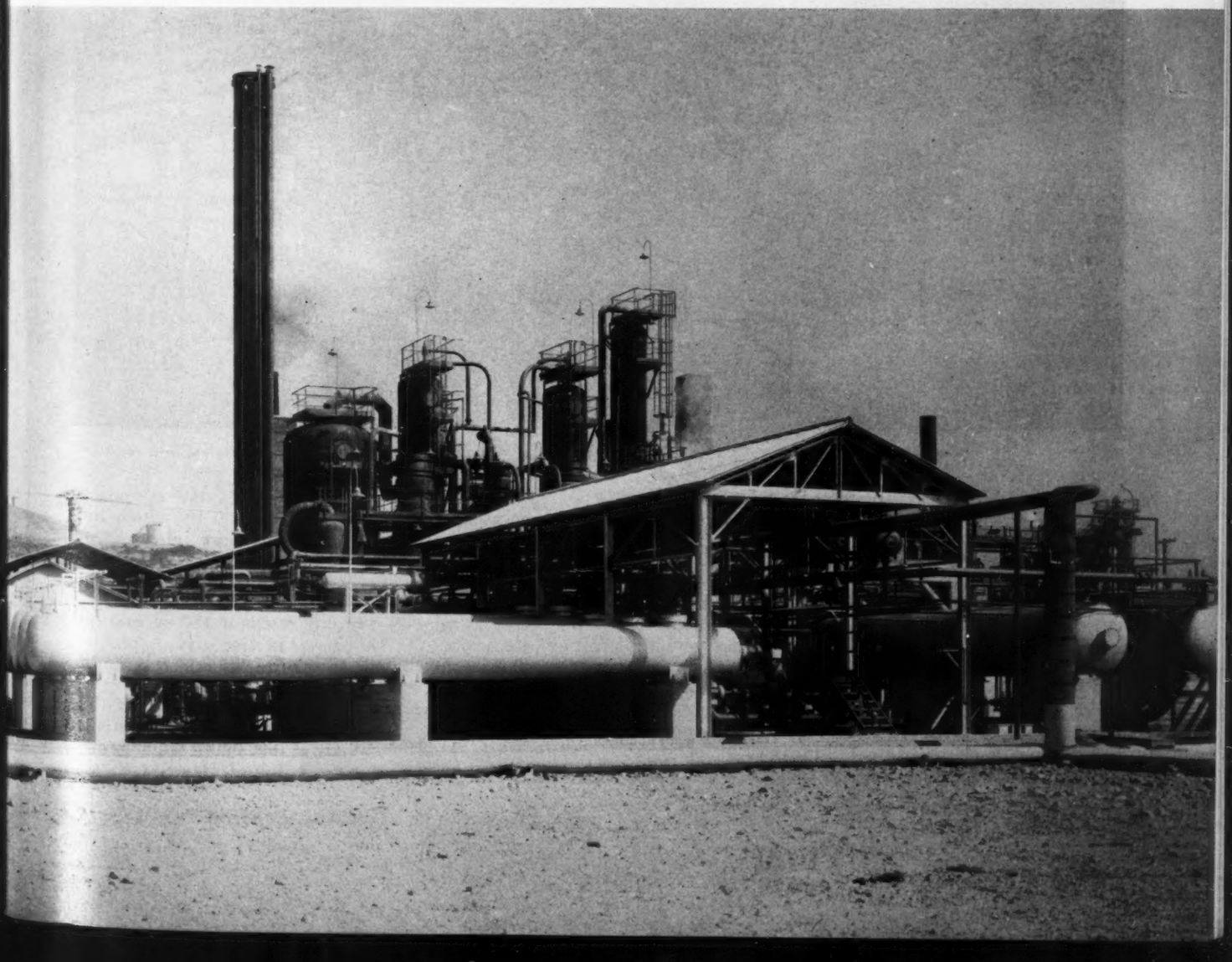
It is this point which is governed by pour test. There is, of course, the argument that viscosity at low temperatures is the controlling factor in cold starting, but until more conclusive evidence is presented the industry accepts pour test as the chief controlling factor. In the past decade only two important refining methods have been available for dewaxing oils. The centrifuge method was economically impractical for producing oils of less than + 20 pour. It also had the serious defect of leaving a high percentage of oil in the petrolatum. Neutrals or wax distillates could not be processed at all. Since 1937 the petroleum industry has rapidly converted to solvent dewaxing.

Solvent Dewaxing

The advantages are many. Almost any type of waxy stock can be handled: cylinder stocks, light and heavy wax distillates and foots oils. Rerunning operations permit obtaining wax of lower oil content or petrolatums of higher melting point. Operating yields are especially attractive because low-oil-content wax cakes are obtained even when running to zero pour. The feature of high yield makes the process invaluable in aviation lubricant manufacture. With the necessity for low pour as indicated above, the refiner would be seriously handicapped without an efficient means of making it.

The individual processes for applying solvent-dewaxing methods vary as to type of equipment and solvent employed. This permits, as we have seen was the case with solvent extraction, a choice of the type best suited to conditions in any given refinery. The benzol-ketone process is the most familiar and ranks first in total operating capacity. Information regard-

Duo-Sol Extraction Process Courtesy, Max B. Miller & Company, Inc.



Furfural Refining Unit Courtesy, Texaco Development Corporation

ing projected and recently completed installations is restricted and, of course, cannot be presented here. It can be safely assumed that the trend[4] of earlier improvements is continuing. Since the first plants were erected much has been done to simplify control and minimize operating difficulties. Instrumentation has reached a high level of dependability. Its importance was felt as early as 1939 when controllers including valves represented[3] 7 to 10 percent of material cost.

Propane dewaxing differs from the benzol-ketone system in that a single volatile solvent is used. Self-refrigeration is optional but pressure filtering must be employed because of the volatility of propane. The process is frequently adapted to permit not only dewaxing but deresining as well. The latter operation is a special form of solvent extraction by which the heavy tars and resins are caused to precipitate from the propane solution of the base stock. This step is applied by warming and settling the dewaxed solution until the desired change in viscosity has taken place. By the removal of 5 percent resins a 180 second oil may lose as much as 25 seconds in viscosity. Asphaltic oils are thus improved in paraffinicity and resistance to oxidation.

The whole question of lubricating quality is the subject of a vast amount of research and experiment. As mentioned earlier, aviation oils made from Pennsylvania crude oil have been found superior to all

others in actual service. Since their greatest distinction is high paraffinicity this characteristic has been thoroughly investigated. It has been found, however, that a highly paraffinic oil (measured by viscosity index) is not always the most stable. Oxidation resistance enters into the problem. At prevailing engine temperatures oxidation causes varnish, carbon, sludge and acid corrosion resulting in stuck rings, pitted valves and excessive crank-pin[5] deposits. Some of these factors are mutually opposed. A highly-solvent-treated oil may develop little carbon but cause serious trouble due to varnish and corrosion. A low viscosity index oil on the other hand may not be corrosive yet result in excessive carbon and high oil consumption.

An acceptable aviation lubricant, then, must be manufactured with a view of meeting all the quality characteristics. High viscosity index must be assured by selecting proper crude oils, solvent treating and judicious use of additives. Oxidation stability must be provided by guarding against excessive solvent extraction and by fortifying natural inhibitors with synthetics. Sufficient dewaxing facilities must be available to reduce pour points without too much dependence upon depressors. In other words, high-grade lubricating-oil manufacture is based on compounding as well as refining operations.

Additives

Numerous authorities have predicted in past years that the day of the straight mineral oil was waning. They saw that future service requirements would have to be met by supplementing natural characteristics with one or several chemical additives designed for a specific purpose. Continual research into the chemical nature of lubricants and the mechanism of oil breakdown has greatly enlarged our understanding of lubrication problems and pointed the way to their solution. Notable as a cause of oil breakdown is the catalytic effect of metals. Iron[6] ranks first in deterioration of oils both in storage and in service. Copper-lead bearings have some effect and silver-lead

Photo by U. S. Army Signal Corps

Truck Lubrication on Specially Provided Grease Rack

somewhat less. Sixty percent of the oxidation and breakdown of oils in new engines is due to the catalytic effect of metals. The effect of iron has been demonstrated experimentally, using an engine with and without a complete interior lacquer coating. Complex organic phosphorus compounds have been found to be useful anti-catalysts. Highly solvent-extracted oils usually require the addition of oiliness agents such as certain ketones and phosphates, and sulphurized sperm oil[1] but their extended use may result in pitting. Viscosity improvers are in common use. They permit a lighter solvent treat with consequent higher yield and less danger of corrosive breakdown in the engine. Their effect on physical tests other than viscosity is negligible.

Balance Necessary

Pour-point depressors, principally the chlorinated hydrocarbons, are well known. In the best refinery practice an economic balance is maintained between cost of depressors and cost of dewaxing to produce an oil of given pour test. Even with the large solvent-dewaxing capacity, the industry is estimated to use 60 to 70 tons of chlorine annually in depressants. Newest members of the additives are detergents or cleansing agents typified by certain metallic soaps. Originally developed[7] to purge deposits from diesels, they now find application in gasoline engines operating under severe conditions. Their use has some disadvantages in that they often promote oil oxidation and may break down themselves into corrosive products. Such side effects are counteracted by proper inhibitors. Further development of these compounds will doubtless eliminate the disadvantages.

The non-military use of additives has been restricted to conserve strategic materials. As noted above, pour-point depressors account for chlorine in tonnage quantities. Other additives require sulphur, phosphorus, tin, aluminum, and many organic compounds, such as phenol, cresol and the alcohols. This emphasizes the necessity of obtaining aviation lubricants by careful refining of selected crude oils. The entire problem of lubricant breakdown and control by additives is definitely tied up with the chemical constitution of petroleum. This subject is being given intensive study[8, 9, 10] with the view of paving the way to synthesis of new and better lubricants. Aviation will share in the benefits but it is not possible to say now whether synthetic aviation lubricants are in sight.

One of the serious obstacles to rapid development of new lubricants and additives is the lack of quick, accurate methods of evaluating them in the laboratory. Manufacturers of transformer oils will testify that the problem is not easy. They have been looking for 20 years for such a test. The various aircraft manufacturers have their stability and corrosion tests and the Navy its work-factor test but the greatest reliance is placed only on full-scale engine tests.[1, 4] These are both slow and costly. At Wright Field such a test costs $1500 and requires 14 barrels of oil. With thousands of possible inhibitors to choose from, it is easy to see the difficulty of finding the best ones. Engine tests are invaluable, however, in establishing the suitability of an oil. They require expert supervision and interpretation but are the best assurance that American-made aviation lubricants are the best that can be made.

Because of wartime restrictions a review of aviation oil production must be very general. No attempt has been made to describe recent developments. Minor changes in operating practice will adapt motor-oil-refining methods to the manufacture of aviation oils. The petroleum industry is prepared with selected crude oils and refining facilities to furnish our armed forces and allies with their requirements of aviation lubricants.

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Replenishing Oil in an Official Car Photo by U. S. Army Signal Corps

Official Photograph,
U. S. Army Air Forces

Post-War Gasoline

GRAHAM EDGAR, Vice President, Ethyl Corporation

ANY predictions concerning post-war gasoline, or any other phase of the post-war world, must be made with very considerable reservation. However, what post-war gasoline could be is by this time fairly well established.

In the first place, it can be said with assurance that aviation gasoline will be much more important after the war than before, and that 100-octane-number aviation gasoline, or better, will be the quality generally employed. No one can predict with certainty the part which aviation will play in post-war transportation, but it will undoubtedly be a far greater part than in the pre-war era, and will probably expand into the field of fast freight movement as well as the mail and passenger field. High power output and fuel economy will be of utmost importance, and gasoline quality will, therefore, be as important as it is for military purposes.

But what of the future of motor gasoline? The tremendous demand for high-octane aviation gasoline together with the program for synthetic rubber has brought about the erection of greatly increased catalytic-cracking capacity, and this capacity undoubtedly can and will be used after the war to produce motor gasoline of high anti-knock quality. Plants for producing the alkylate so necessary for aviation gasoline will have capacities probably much greater than the post-war demand for aviation gasoline, as great as they may be expected to be. Plants for producing toluene and other aromatics probably will be available. Furthermore, the research and development laboratories of the petroleum industry,

TODAY'S FIGHTING FUEL IS TOMORROW'S MOTOR FUEL

Light Tank Taking on Gasoline in Army Maneuvers

Photo by U. S. Army Signal Corps

Refueling Curtiss P-37 Official Photograph, U. S. Army Air Forces

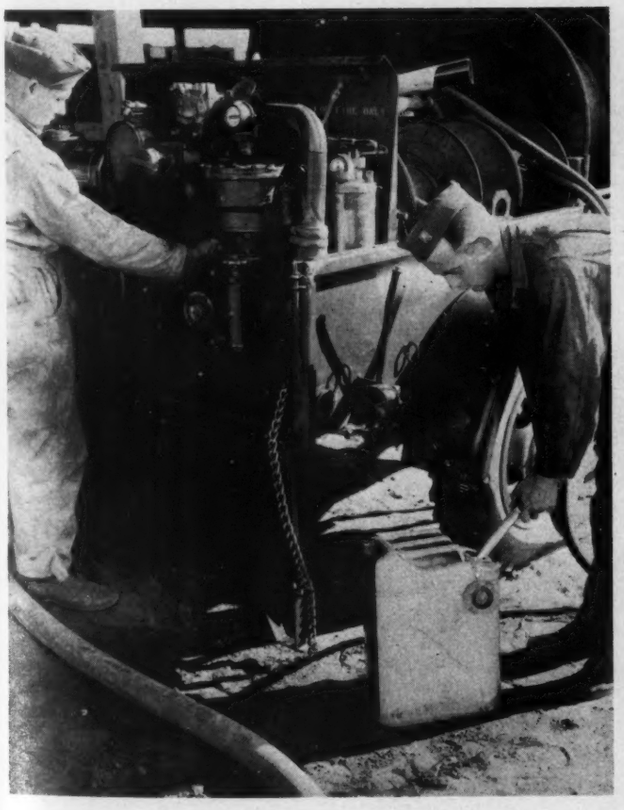


Photo by U. S. Army Signal Corps

Gasoline Dispenser Showing Pump Motor and Main Induction Hose

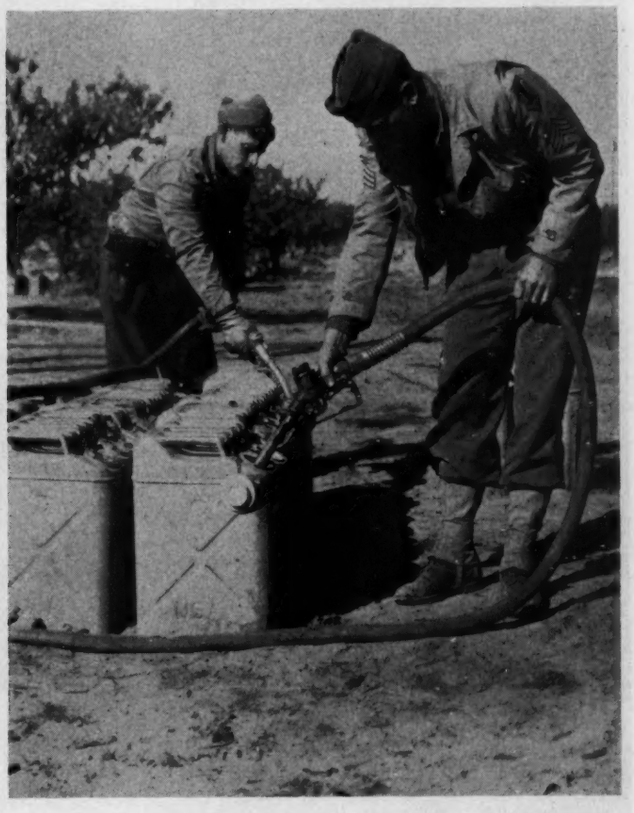


Photo by U. S. Army Air Corps

Filling Five Gallon Cans from Dispenser

always alert, have been profoundly stimulated by the war effort and can be counted on for processes which are improvements over what we have today. I believe it to be conservative to say that the petroleum industry will be in a position to produce motor gasoline of much higher effective anti-knock value than that which was produced in 1941. One might guess that gasoline approximately equivalent to the premium grade of 1941 (say, 80 octane number) could be produced as a house-brand gasoline, and that premium gasoline having an effective anti-knock value of between 90 and 100 octane number could be produced.

Will such gasoline be produced and marketed? The answer to this question depends largely upon the automotive engineer. The automotive industry finds itself at present in a position unique in its history. Heretofore, under the continued pressure of getting out yearly models, desirous of reusing as many tools, dies, etc., from previous models as might be feasible, and doubtful of public acceptance to too radical a change in car design, the automotive industry has made all changes conservatively and gradually. In fact the saying is that the only reason that engines are still in the front of the car has been that no one could figure out a way to move them to the rear gradually. Now, the situation is that there are no yearly models, or production of cars of any kind, which gives the design engineer a breathing space in which to plan far-reaching improvements. Tools and dies will have been largely scrapped long before automobile manufacture can begin again. Metals, such as aluminum and magnesium, will be available in quantity and at reduced price. New and better plastics will be available. Coupled with this will be a car-hungry public. What will the answer be? As far as body design goes, one can look forward with confidence to radical changes, but what of the engine? Will we have an engine of extremely high compression ratio, and consequent high thermal efficiency? Will there be a small supercharged engine capable of producing the necessary power with savings in weight and size? Will there be an engine of very moderate speed range equipped with automatic transmission? Will there be an engine embodying principles quite different from the conventional engine of today? No one can answer these questions, but it appears certain that no real developments along these lines can be expected unless the petroleum industry does its share by improving gasoline quality.

Are we reasoning in a circle in saying that improvement in the engine of the future depends upon the gasoline of the future, and that the gasoline of the future depends upon the engine of the future? No more so than has been true in the past; the two industries have always advanced together and must continue to do so. The only difference is that heretofore progress has been made by a steady series of small advances, made first by one industry and then by the other, or by both together; now, the war has brought about the possibility of fairly abrupt and substantial advances in technical progress. There are many serious problems, economic and technical, in such progress, but I cannot believe them to be insuperable.

Distribution of Gasoline by the Quartermaster Corps During Maneuvers Photo by U. S. Army Signal Corps

Research . . . Its Role in Petroleum Chemical Progress

WAR, the most destructive activity in which the human race engages, is also the strongest activating force for the speeding-up of inventiveness and the development and production of new materials. Time and again new fields have been attacked by all the concentrated forces at the command of a whole people and within two or three years greater achievements have been realized than those which may normally be expected in as many decades. Improvements in existing processes and products are generally part of these developments. In addition, either new processes are perfected or old processes are applied to radically new purposes.

Such changes are made at a pace which would not be risked in peace. Monetary values cease to exist for a people fighting for existance. Exigencies of war make imperative speed, daring and chance-taking in process development which may be costly in money and materials, but which frequently nets the most amazing returns, both in the products which are made available and in the properties and applications which are discovered. A striking example in World War I was the synthesis of ammonia which subsequently became a peacetime operation.

Global war is demanding of the American people the production of super-products in quantities which were beyond the imagination of most of us two years ago. It is demanding those products at rates which may appear greater to many than human ability and human endurance can maintain. The American people are demanding of their engineers, chemists and manufacturers the development in a few months of processes, of products and the "know-how" of their use which in peacetime would require at least a decade to achieve. Products are demanded of which we had only general ideas a few years ago. Yet, oil technologists will make commonplace in a few months, products which in the immediate past were scientists' curiosities, and which normally might be hoped for only by the next generation.

All this progress and this achievement emerge from one door—research. The present position of research in the sequence of adapting petroleum products to consumer needs is diametrically opposite from that of a few years ago. In the earlier years of the industry, the market was ready-made and tremendous in volume. Technical problems were mainly those of increasing production to satisfy this market. We had a simple product relatively unchanged from its natural condition, about which we knew little. we had few tools with which to pry into this material Its possibilities were so great that the consumer adapted his operations, machines and purposes to the product. When Otto in 1876 attacked the problems of the four-cycle internal-combustion engine first invented by de Rochas, he adapted it to the light distillates from petroleum. The first oil well had hardly gone on the pump when this adaption started the development of automotive power which has made the petroleum industry a dominant factor in modern civilization. The consumer willingly took the combination of engine and light hydrocarbons as they were offered, glad indeed to have even this relatively inefficient power-source. Research had not yet begun to dent the dense wall of ignorance of petroleum and its utilization.

Motor Fuel Development

Research workers could not long allow such a versatile raw material to be utilized inefficiently or without investigation of its potentialities. The ubiquitous chemist began to explore and to take apart. He did this crudely at first because this was virgin jungle. His tools were few and inefficient, and his funds limited. Motor gasoline had one yardstick of quality—gravity. Research was busy for a generation with the problems of segregating by distillation and of partially purifying by chemical and physical means the materials which, when finished, were still decidedly raw in the light of present knowledge.

Consumers began to call for, and competition to demand better materials. Economics was forcing the petroleum industry to look for outlets for the residue of the crude oil and for means of increasing the yield of salable products. The automotive industry grew so rapidly that to supply it alone became the primary job of the oil industry. Engine research began to develop knowledge about engines and their betterment. Automotive engineers and petroleum investigators encountered premature or spontaneous combustion of hydrocarbon fuels under compression. Midgley and Boyd discovered the effects of organometallic compounds in suppressing this premature or spontaneous combustion called detonation. At this same time, cracking was being developed to produce more and better gasoline from a barrel of crude. These two developments—cracking and the knock suppressor, tetraethyl lead—made possible the great strides in motor-powered transportation in the last quarter-century.

Research began to have an increasingly important role in the direction of refining and manufacturing processes. Technologists began to evaluate petroleum products in terms of their service characteristics. Steady progress was made in the production of materials capable of improved performance, and the design and efficiency of utilization equipment was no longer limited to the performance of the naturally-occuring raw materials. Enough of business management understood the possibilities of-

fered by this technological transition to maintain the trend, and the petroleum industry became a leader in the application of industrial research.

Octane Number Scale

After strenuous wrestling by technologists with the problem of producing anti-knock fuels and methods for evaluating the detonation property, Graham Edgar proposed iso-octane (2,2,4-trimethylpentane) and normal heptane as standards for anti-knock measurement, and the octane-number scale was developed. In the attempt to produce fuels which take advantage of the new-found facts in fuel and engine technology, the chemist-engineer called in his most useful aid—Synthesis. In that field in very recent years, polymerization, alkylation, hydrogenation and dehydrogenation, isomerization, condensation, catalytic cracking and other methods of fuel synthesis have been developed, to change the whole internal-combustion-engine-fuel panorama. The petroleum scientist has taken a major part in promoting the role of the oil industry in modern life.

In many fields such as lubricants, compression-ignition engines, and aviation, research undertook avidly the job of fitting the characteristics of petroleum products to the services required of them. Discussion of these items could be expended enormously without repetition. In many respects fuel qualities were improved more rapidly than the engines powered by them. It was in this state of rapid technical advance that the War deluged the petroleum industry with the extremely accentuated and critical demands which are now straining every capacity which we possess.

Aviation Fuel Progress

When the shadows of War began to thicken as the Nazis built their war machine, the production of 100-octane-number aviation fuel in quantities much beyond test-tube amounts was still in the experimental stage, and the sudden expansion to come was unexpected by all except the most forward-looking investigators. Polymer hydrogenation was known and used only to a limited extent to prepare commercial iso-octane. The use of addition agents to fortify lubricants to withstand the terrific punishment of the stepped-up airplane motor, the heavy-duty industrial carrier and the ponderous military vehicles in use and to come was demanded by few, recognized by some and unacknowledged by the great majority of industrial leaders.

By polymerization-hydrogenation and by the simpler alkylation methods, chemists and engineers developed the processes for combining insoparaffins and olefins from the light ends of petroleum and natural gas or produced, by cracking and other methods, to make synthetic blend agents approaching 100-octane number. Isobutane was combined with ethylene to form neohexane, possessing high octane number and other desirable qualities. By virtue of these developments, supplies of blending agents were provided to meet constantly expanding requirements.

The production of high-octane-base stocks with suitable volatility for use in aviation fuels is one of the big problems of the petroleum industry. In most instances, the base stock is a selected fraction of straight-run naphtha or natural gasoline, the selected fraction having a comparatively high octane number. Since these stocks are difficult to obtain economically in large quantities by conventional fractionation, the technical branch of the industry, laboriously and with meticulous attention to detail and scientific principles has developed super-fractionation. This improved fractionation is being used to segregate higher-quality-base stocks, which in turn produce higher quality aviation fuels.

Super-fractionation is being applied commercially also to the concentration of individual hydrocarbons as well as narrow-boiling groups and to separation of the light hydrocarbons employed as liquefied gases and as intermediates in the synthesis of a host of industrial and commercial products. It is to this still very new chemical branch of the oil industry that the chemist and engineer are now giving increasing and concentrated attention.

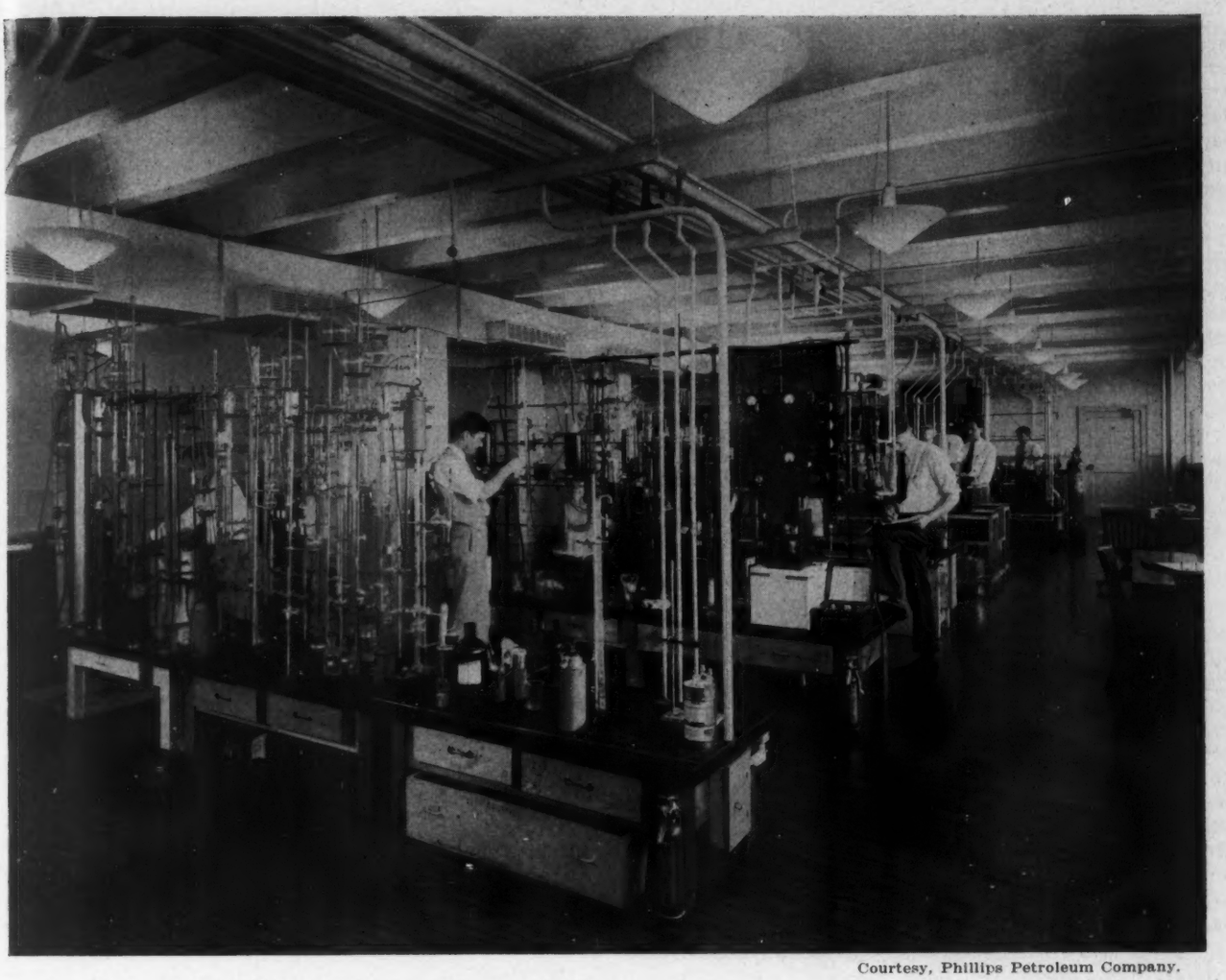
Catalytic Cracking

Catalytic cracking of heavy oils has been developed as a means of producing more light hydrocarbons, particularly butylenes. At the same time, there is formed some stock suitable for blending in aviation fuels. Catalytic cracking produces these products at lower temperatures and pressures than required in pyrolytic cracking. Also, the motor fuel produced by catalytic cracking possesses higher anti-knock characteristics than conventionally-cracked fuels. Research scored again, brought out the process needed—in fact, had it ready before the need arose.

Aromatics for Explosives

War demands huge quantities of explosives, many of which are synthesized from aromatic hydrocarbons. For example, in the case of benzene and toluene, the wartime requirements far exceeded the capacity of facilities producing these compounds from coal. To relieve this situation, large-scale production of these aromatics from petroleum was undertaken, utilizing conversion and recovery processes developed by research within the petroleum industry. These petroleum processes are being put into commercial operation at a rate inconceivable under the ordered economic conditions of peacetime. Noteworthy developments in this field include the methods for producing toluene by the catalytic cracking of heavy oils, the pyrolysis of gaseous hydrocarbons, and the catalytic dehydrogenation, aromatization or dehydrocyclization of selected light liquid hydrocarbon fractions.

Of possibly less scientific interest, but of a practical importance paralleling that of aviation and other special fuels, is the reinforcement of lubricants to endure the increasing demands placed on them by the current service conditions. Doubling and even trebling the unit pressures on friction parts of aviation engines bring lubricants to and beyond natural limits of film maintenance and useful life. The research chemist and the experimental engineer collaborated in finding additive products to fortify lubricants and to permit engine and fuel designers to capitalize on the advantages which may be gained by designing for these improved lubricant properties. These additives have included organic salts, sulfides, chlorides, nitrogen compounds, and a whole galaxy of complex organic products adapted with different degrees of success to lubrication betterment—another part of research's job of fitting the product to its uses. More purely synthetic methods for preparing lubricants by the combination of olefins, polyolefins, aromatics and napthenes are coming to the fore. Special characteristics such as control of viscosity



Courtesy, Phillips Petroleum Company.

Development of analytical methods by oil company, university and U. S. Bureau of Standards laboratories has aided greatly in perfecting new commercial processes.

change, fluidity control and resistance to molecular rupture are improved by the synthetic products of olefin-aromatic polymerization and condensation, by the chemical additives mentioned above and by the extension of conventional refining methods.

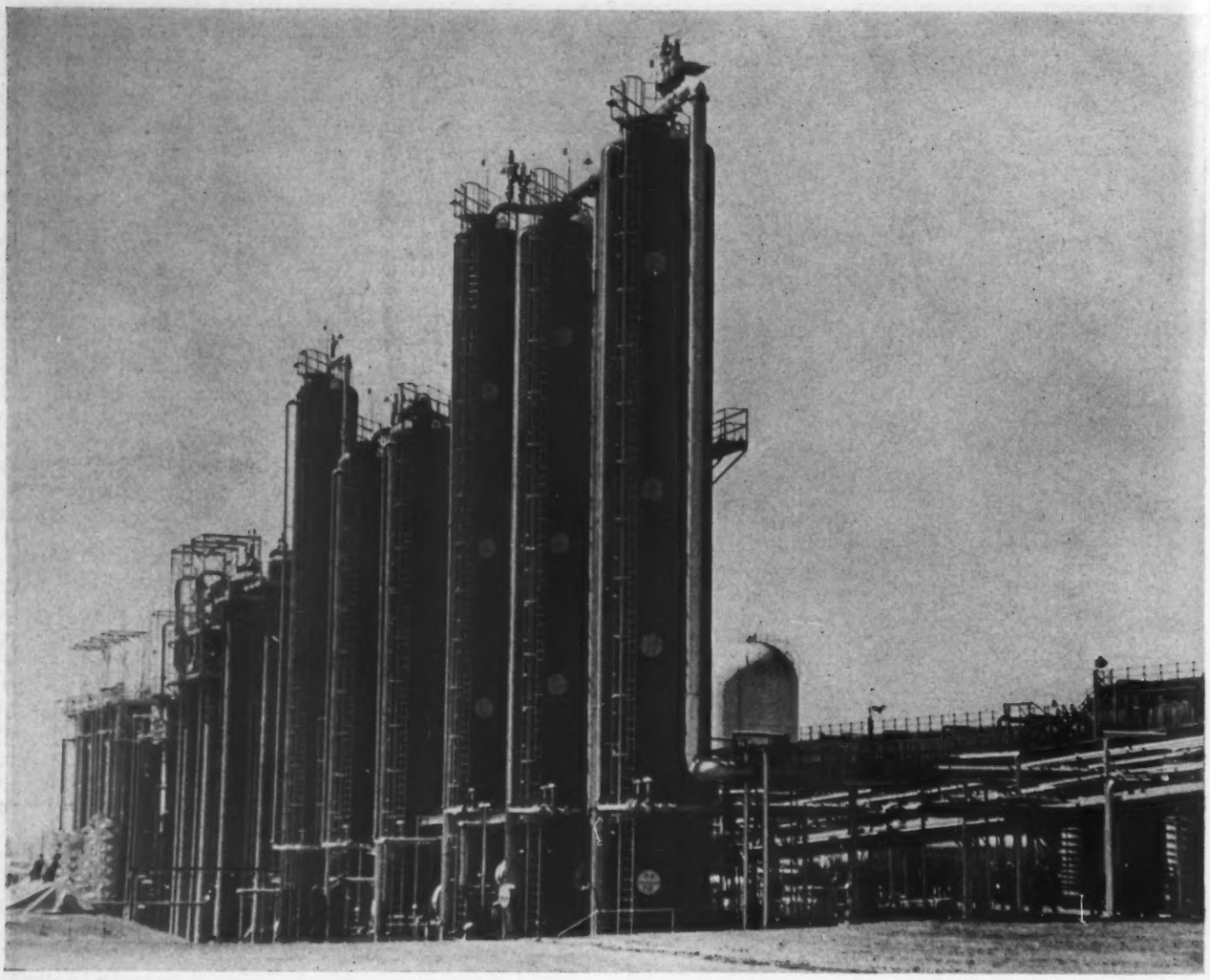
Rubber

Enemy invasion of the East Indian rubber-producing regions cut off natural rubber supply and presented the critical problem of producing synthetic rubber to the petroleum, rubber and chemical industries overnight. For two generations, chemists had worked unhurriedly to know more of rubber and its synthesis, with the commercial significance and scope of their work limited by the availability of the natural product. However, several organizations here and abroad had developed feasible processes for rubber synthesis, most of which utilized the hydrocarbon butadiene.

In developing quickly the huge supply of butadiene required for the synthetic-rubber program, the utilization of petroleum hydrocarbons as raw materials was a logical approach. Adequate volumes of the hydrocarbons were available, and the technological experience accumulated through direct and related research was applicable to the various manufacturing processes. Butadiene may be made, for example, by catalytic dehydrogenation of normal butane or normal butylenes derived from petroleum. Other routes include the pyrolytic or catalytic cracking of liquid hydrocarbons, the pyrolysis of hydrocarbon gases, and synthesis from alcohol. Every phase of manufacture and purification is guided by research in hydrocarbon chemistry.

Subsequent stages in the manufacture of synthetic rubber from butadiene introduce a number of additional compounds and products available with relative ease from petroleum and chemical industries. These include comonomers, such as acrylonitrile and styrene, chemical plasticizers, inhibitors, accelerators, carbon black and other necessary adjunctive materials. More and more of these materials will be synthesized from petroleum hydrocarbons. Many of the manufacturing processes were known and in operation before the emergency arose, as a result of research in the petroleum, rubber and chemical industries. Without the present foundation of technical information and forward-looking research minds, it is doubtful if sufficient synthetic rubber could be produced in time to save us from defeat in this mechanized war. Without rubber, the war is inevitably lost.

Important in war and of even greater potential importance in peace are the increasing demands for hydrocarbon raw materials and chemicals from petroleum. Hydrocarbons of various types, ranging from the simplest paraffin of one carbon atom to paraffins, naphthenes and aromatics of higher molecular weight are potentially available from petroleum.



Courtesy, Phillips Petroleum Company.

Super-fractionation employing as many as 150 plates has made available large quantities of pure hydrocarbons such as iso-pentane for aviation gasoline blends.

The limitation on the number and purity of the individual hydrocarbons recoverable from petroleum are at present the limitations of the methods available for resolving the very complex mixtures in which the higher-molecular-weight compounds occur. However, the lower-molecular-weight hydrocarbons which have already been segregated in high purity from the less complex mixtures represent the raw materials for chemical manufacture on a tremendous scale.

Super Fractionation

One of the basic methods by which these hydrocarbon raw materials are obtained in suitable purity is extremely precise fractionation, or so-called superfractionation. Whereas distillation columns of 30 to 50 plates may be considered adequate for fractionation of conventional refinery products, superfractionators may employ 150 plates or more. Such equipment is used, for example, in separating butadiene and butylenes in high purity from C_4 hydrocarbon mixtures. In the fractionation of normally gaseous hydrocarbons, refrigeration is often employed to condense compounds boiling as low as ethane and ethylene and aid in recoving these dyhrocarbons in high purity. Reflux ratios are usually high, and ma yreach 100 to 1. Temperature control is exacting, since a variation of one or two degrees may affect the fractionation. Control of the entire operation is most exacting, and the skill necessary to design and operate such equipment results from careful technical study and long practical experience in meeting rigid product standards.

By such methods, families of light dydrocarbons have been isolated and made available to the industry. Some pure hydrocarbons are available in quantities sufficient to supply large scale manufacturing operations. Others still are obtainable only in small quantities primarily for the use of research laboratories. A catalog has been published by one oil company listing 41 pure and technical hydrocarbons for the use of laboratories and manufacturers. The pure hydrocarbons have a guaranteed minimum purity of 99 mol-percent. Not long ago hydrocarbons of such purity were a costly rarity.

Tribute should be paid here to the United States Bureau of Standards and to other investigative agencies such as the universities and oil company research laboratories for the superb work they have done and are still doing in the development of analytical methods and in isolating and identifying individual hydrocarbons to increase our knowlege of the composition of petroleum.

Use of Hydrocarbons

Let us examine some of these groups of hydrocarbons and observe how they may be utilized. The first two in the paraffin hydrocarbon series, methane

and ethane, are of less wide application in our present technology, yet they have been employed in the synthesis of a large number of commercial and industrial products. Methane is oxidized under carefully controlled conditions to form methyl alcohol, acetone, formaldehyde and formic acid. Other reactions produce methyl halides, sulfides, cyanides and other chemicals by substitution of one of more of the hydrogen atoms of the methane-molecule. These products may be used as such or may be used to insert methyl, methoxy and thiomethoxy groups into many compounds such as dyes, Pharmaceuticals, lubricant addition agents, and others. From ethane an analogous line of products is made and for the same general purposes.

In addition to these indicated uses, ethane may be converted by dehydrogenation to the corresponding olefin, ethylene, and this compond, whether derived from ethane or from the conversion of other hydrocarbons is one of the most versatile and important hydrocarbon raw materials. Within the petroleum industry, ethylene is employed in alkylation reactions with isoparaffins to produce neohexane and other high-octane alkylation products. Alkylation of benzene produces ethylbenzene, which is convertible to styrene required for synthesis of Buna rubber, and a series of valuable plastics. Polymerization yields butylenes and higher polymers for fuels and lubricants. Still further processes utilize ethylene to produce ethyl alcohol, ethylene glycols, ethylene oxide, ethylene dihalides and whole families of organic solvents including esters, and ethers, amino-alcohols and polyamines.

The utilization of ethylene in chemical synthesis has beeen promoted by the fact that ethylene is readily separated from higher-boiling hydrocarbons and obtained either in pure form or in mixtures containing no other reactive components. The use of the higher homologues is made practicable by the processes which furnish them in concentrated form and relatively free of reactive impurities. As mentioned above, the basic tool for this separation is superfractionation, although with C_4 and higher mixtures containing different hydrocarbon types (olefins, diolefins, naphthenes, etc.) the use of solvent extraction or azeotropic distillation is assuming particular importance.

Propane, the next member of the paraffin series, is known chiefly as a liquefied fuel and an important source of heat and power. By high-temperature conversion processes, propane yields ethylene, butadiene and other hydrocarbons, including propylene, the olefin of corresponding structure. Propylene is utilized in polymerization reactions to produce hexenes and higher polymers, while alkylation reactions produce insoparaffin mixtures for aviation fuels and propylated aromatics. The chemicals which may be prepared from propylene correspond to those enumerated for ethylene, and the propyl alcohols, glycols, glycerine, dihalides and polyamines are of commercial importance.

Most Important Hydrocarbons

The C_4 hydrocarbons— butane, isobutane and the butylenes—may well be called the most important hydrocarbons in petroleum today. In diverse uses ranging from liquefied gas to the production of synthetic rubber this family assumes a stellar role, so far as an indispensable one. The list of products obtained from the C_4 hydrocarbons is long and it is growing with gratifying rapidity. The best known use of isobutane is in alkylation whereby it is condensed with butylenes by means of sulfuric or hydrofluoric acid to form iso-octane, one chief ingredient of aviation fuels. Butylenes or isobutylene are polymerized and hydrogenated to produce iso octanes for the same purpose. Similarly isobutane is combined with other olefins, as propylene, pentenes and

Research laboratories of most oil companies are working around the clock to aid in producing more and better products for the War. Above is a night view of Phillips Petroleum Company Research Laboratories at Bartlesville, Oklahoma.

isopentenes to form aviation-fuel components, employing alkylation catalysts. Cracking under rather severe conditions converts a portion of the charge to the diolefin, butadiene, the major constituent of practically all formulas for synthetic-rubber making. By the use of catalytic dehydrogenation increased yields of butadiene are obtained under more advantageous and more economical conditions. Isobutylene is formed from isobutane over dehydrogenating catalysts or by simple pyrolytic cracking and becomes the main constituent in so-called butyl rubber.

One use of normal butane, which makes up more than half of the total available C_4's is conversion to butenes —1 and —2. Catalytic methods have been developed to produce these more reactive olefins for alkylation and polymerization-hydrogenation syntheses. These compounds are also dehydrogenated to butadiene with relative ease by catalytic methods. Butadiene and the C_4 olefins may be employed in a remarkable number of chemical syntheses to produce alcohols, glycols, di- and tetra-halides, ketones and an entire series of chemical derivatives. The research chemist is rapidly extending the list of products obtainable from these very reactive petroleum derivatives and developing processes and catalysts by which the reactions may be accomplished. Ethyl and vinyl acetylene offer to the researcher a versatile and reactive intermediate for present and future syntheses.

The supply of C_4 hydrocarbons in the United States was estimated recently as nearly 200,000 barrels per day, readily available in refineries and natural gasoline plants, of which about one fourth is isobutane and about one half normal butane. The total potential supply of these products in this country reaches nearly the 400,000-barrel mark, but about half of this volume is not readily available at present. Our national resources of readily available normal butane are large enough to produce two to three times as much rubber as was consumed in the United States in the peak consuming year before Pearl Harbor—this without calling on the alcohol industry. The total potential supply of normal butane is thus four to six times as large as needed to supply butadiene for manufacturing our largest pre-war rubber demand without making any inroads into the supply of isomers or butylenes which are needed for aviation gasoline. Reference is made here to only the ordinary butane sources and not to the added quantities which could be obtained by cracking additional volumes of heavy oils or by more severe cracking procedure.

In the pentane family an even greater variety of raw materials is available, though at present the C_5 hydrocarbons are not utilized to the extent indicated for C_4 hydrocarbons. Isopentane is employed mainly in aviation and motor fuels. Because of its high octane number and volatility, thousands of barrels daily are required for our military and commercial aviation engines. The amylenes are valuable also for alkylation in making higher-molecular-weight aviation-fuel components.

Normal pentane is dehydrogenerated to form pentenes and pentadienes which offer most interesting possibilities in rubber manufacture and in a host of chemical utilizations paralleling those mentioned for the butylenes. Pentadiene may be obtained from isopentane by catalytic dehydrogenation. Cyclopentane displays valuable properties as a motor and aviation fuel. It may also be oxidized to produce cyclic ketones valuable in chemical syntheses and as solvents.

The major field for the C_6 to C_9 parafins and olefins at present is in motor and aviation fuels. For aviation especially, isohexanes, isoheptanes, iso octanes and isononanes are being segregated by the superfractionation methods, to augment the amounts of these produced by the above outlined processes. In general these compounds are applicable to processes for chemical synthesis which are analogous to those described above for the lower homologues. The primary step toward their more efficient study and utilization by research and industry has been perfected to a creditable and efficient degree—that of concentration and of separation from other products, that research or direct use may be carried out.

The same attitude may be assumed with regard to higher hydrocarbons, and the possibilities are imagination-staggering. For the research worker of 1942 the work already in hand is intriguing enough and voluminous enough to occupy the combined energies, minds and ingenuity of every available chemist and engineer in these United States for decades to come.

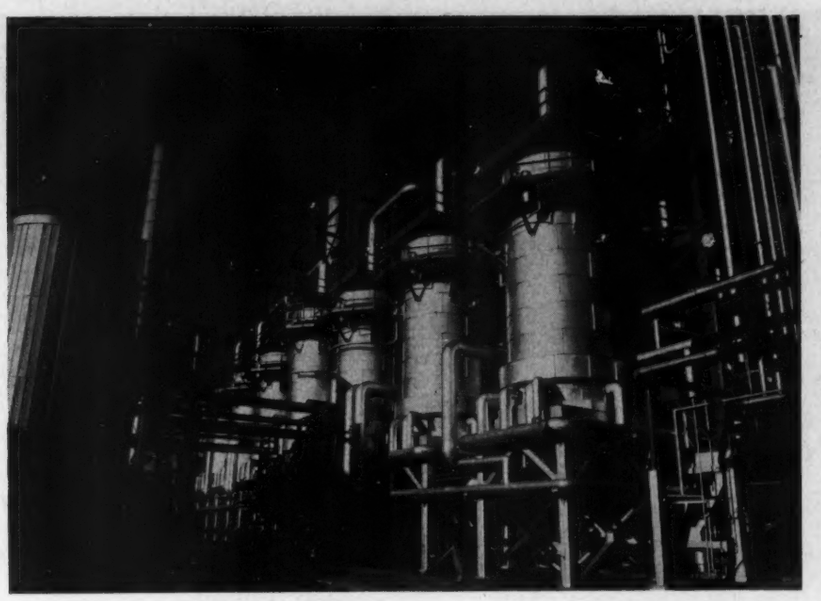
In contemplation of tomorrow's possible and probable developments, the usually conservative imagination of the chemist may safely run riot. With one foot on solid ground of actual achievements, crystal-gazing becomes less hazardous.

"Bill" Stout said recently, in discussing private plane operation, that he could see in the relatively near future an airplane engine "of 100 horsepower, weighing 100 pounds, costing $100," which will make available economically a satisfactory "hedge-hopper" plane to the individual of moderate income, the "Model T" of the masses. To make such an engine a reality, synthetic fuels must become as common as superior motor fuels are now. The fuel efficiency must equal that of the weight-power efficiency of the engine. Lubricants must carry unit loads typical now only of extreme pressure equipment conditions, 10,000-20,000 pounds per square inch or some other hitherto unheard of value.

George Maverick said some years ago that the lubricating oil of tomorrow will be an "assembled oil"; each part isolated, synthesized or purified to contribute its own special quality to the end product. The finished lubricant will possess this assembly of desirable properties and be free from the deleterious materials which must now be accepted along with the qualities necessary for the purpose.

To accomplish these things petroleum will be, and to some extent already is, taken apart, dissected to obtain the unit materials from which the highly complex fuels of tomorrow will be synthesized. Alkylation, polymerization, hydrogenation and other processes have been operated successfully on a commercial basis, but still are being studied in a hundred laboratories to approach greater perfection. Catalysis appears to be the Aladdin's lamp of the chemist but the rubbing is hard, tedious and long.

By learning the properties of hydrocarbons through endless experiment we learn their uses and advantages. By following the long trail of chemical principles we learn new processes for effecting reactions not possible before. By the concerted labor of thousands of minds the technology and the chemistry of petroleum is extended. These hydrocarbon raw materials are converted to improved and multiplied products for today and tomorrow.



Houdry Catalytic Butadiene Process

ADAPTATION of the Houdry Catalytic Cracking process to the making of butadiene consists either of processing butane through two stages of dehydrogenation or of processing mixture of butane-butylene feed through one stage of dehydrogenation. In each type of operation purification of the final product of dehydrogenation consists of separating it from other hydrocarbons by solvent extraction. Here the butadiene is picked up by the solvent, while other hydrocarbons are released for recycling back through the dehydrogenation process. Finally solvent and butadiene are separated and butadiene is ready for storage.

Units of 15,000 tons annual capacity are being recommened by the Houdry Process Corporation for areas where butane is available in connection with natural gasoline plants, recycling operations or refining plants. Sun Oil Company is building a unit of this capacity for processing butane from refining operations. Construction is for Defense Plant Corporation and butadiene production will be supplied to Rubber Reserve Company.

Small capacity of these units fit them into the program of quick expansion of butadiene production. Design allows 60 to 75 percent of equipment to come from existing plants or from second-hand equipment available in the area. The plant under construction by Sun Oil Company involved gross estimated expenditure of $3,254,420, while actual value of the material being used is $1,720,000, of which only $313,686, or 18.2 percent, represents new critical materials requiring priority.

Other advantages advanced by Houdry Process Corporation are that units of this capacity can be in operation within six months after construction is started and that the units can be converted after the war to the production of high-octane gasoline and components of aviation gasoline at reasonable cost.

Availability of butane is cited by Houdry officials as advantageous for butadiene manufacture. From statistics of the United States Bureau of Mines for 1941 and five months of 1942 the potential normal butane supply is:

	Bbls. Daily
From natural gasoline plants	92,000
From cracking process at refining plants	36,700
From crude oil run at refining plants	50,400
Total	179,100

Their conclusion is that at least 175,000 barrels of butane daily are available for processing.

Although a mixture of butane-butylene can be used and one stage of dehydrogenation eliminated, normal butane is recommended because of the supply as well as its availability at refining plants as a by-product of alkylation plus the fact that the use of butane does not cut into the raw materials used in making 100-octane aviation gasoline as would be the case with the use of butylene as the feed.

Much less than the daily quantity of butane potentially available would be required to make butadiene sufficient to meet the current program for synthetic rubber from petroleum. On the basis of the high butadiene yield obtained from the Houdry

TABLE 1

Representative economic statement for Houdry Butane Dehydrogenation Unit (15,000 tons per year Butadiene capacity), including Butadiene Purification.

Basis: One Calendar Day

	Base Price, Dollars	Quantity Per Day	Dollars Per Day	
Debits:				
Catalyst			165	
Solvent			216	
Inhibitor for butadiene			10	
Operating Labor:				
Process plant, 10 men	1.20 per Hr. each		288	
Laboratory, 5 men	1.20 per Hr. each		144	
Undistributed and supervisory			100	
Utilities:				
Electric power	0.007 per KWH	33,600 KWH	235	
Fuel burned (6,000,000 B.t.u. per bbl.)	1.10 per bbl. (del'd. Texas or Okla.)	309 bbls.	340	
Steam (from fuel oil or gas)	0.33 per 1000 lbs.	2,040 M. lbs.	673	
Cooling water	0.008 per 1000 gals.	10,030 g.p.m.	115	
Makeup water	0.15 per 1000 gals.	300 g.p.m.	65	
Maintenance (excl. boiler house and water system)			500	
Taxes and insurance			83	
				$2,934
Butane feed	0.06 per gal. or $2.52 per bbl.	677 bbls.	1,706	
General administrative cost ($0.075 per lb. butadiene)			684	
Royalty at $0.00125 per lb. butadiene			115	
Total debits				$5,439
Credits:				
Fuel gas	1.10 per bbl.	158 bbls.	174	
Total cost (excl. amortization)				$5,265
Cost of butadiene (excl. amortization based on 66.9 percent yield from butane	0.06421 per lb.			

NOTE: If process steam is first expanded through drivers, electric power requirements may be correspondingly reduced.
If steam or gas driven refrigeration compressors or steam jet refrigeration is used, power consumption may be cut by 18,000 KWH per day.

process, 44 such units, each charging 677 barrels per day of butane, would charge a total of about 30,000 barrels of butane daily and produce 660,000 tons of butadiene annually, sufficient for the final production of 880,000 tons of rubber per year. By making the fullest possible use of existing equipment, less than $40,000,000 in new critical material would build these units, according to estimates. It is pointed out that the first 300,000 tons of annual capacity of butadiene could be in operation within 6 to 7 months, and the total required capacity of about 600,000 tons would be available within 9 months from start of construction.

The above figures are based on the high yield of butadiene obtained from processing butane in the two-stage catalytic dehydrogenation units of 15,000 tons per year capacity. The following tabulation shows the material balance for such units.

Butadiene	66.9 weight percent yield
Fuel gas	23.6 weight percent yield
Catalyst deposit	9.5 weight percent yield

Catalyst deposit is burned off in the process. The above material balance allows for losses in the butane absorber and is based on a 90-percent recovery of the butadiene during purification.

Nature of the Process

Equipment for the dehydrogenation phase is similar to that used in existing Houdry catalytic-cracking plants. The charge stock is subjected to dehydrogenating conditions in two stages, utilizing six reactor cases of simpler design than those embodied in the conventional Houdry catalytic cracking units. In the first stage of the dehydrogenation, butane, butylene and lighter gases are produced. Butane and butylene are concentrated in a vapor-recovery system to produce the charge for the second dehydrogenation stage, where butadiene production occurs. Separation and purification of the butadiene may be effected by one of the available purification processes.

A feature of the operation is the recovery and utilization of heat generated during regeneration of the spent catalyst. The catalyst is revivified by burning the carbon deposited on it in a stream of air. The reactors possess sufficient heat storage capacity to eliminate wide temperature fluctuations, and pressure and rate of flow are regulated so as to balance the heat required for the chemical reactions with the heat supplied by burning the carbon deposit. Houdry officials declare that as far as they know the process is the only one in which is developed the technique of utilizing the adiabatic cycle of heat produced in the burning cycle of the carbon as the principal source of heat required for the dehydrogenation cycle.

Operation is designed for quite short on-stream periods during which vapors are flowing through any particular catalytic reactor. Each on-stream period is followed by a regeneration step whereby carbon is burned from the catalyst to maintain it in a very active condition. The useful life of the catalyst is expected to be more than six months. Because of the relatively pure form of the charge stock the carbon deposit is comparatively small.

Because of the fact that operating temperatures are fairly low, requirements for materials, alloy steels and utilities, such as steam, fuel, power and water is kept to a minimum. The attached tabulation of materials shows that chrome steel plate, low-alloy steel bolts, brass, bronze, copper and lead fittings and construction material comprise only a small percentage of the total weight.

TABLE 2

Material requirements for Houdry Two-State Butane Dehydrogenation Unit combined with Butadiene Purification Plant for manufacturing 15,000 tons per year of Butadiene.

	Dehydrogenation and Separation Unit, Tons	Purification Plant, Tons	Total, Tons
Carbon steel plate	293	250	543
Structural steel	484	143	627
Reinforcing steel	63	19	82
Tubular steel	1,015	360	1,375
Steel forgings	68	38	106
Forged steel valves	3	2	5
Cast steel valves	234	38	272
Cast steel castings	109	....	109
Carbon steel bolts	10	3	13
Total carbon steel	2,279	853	3,132
Cast iron castings heat resisting	42	34	76
Cast iron castings	15	....	15
Cast iron valves	25	13	38
Total cast iron	82	47	129
27 percent chrome steel plate	30	....	30
Low alloy steel bolts	10	3	13
Total alloy steel	40	3	43
Cast brass valves	1	1	2
Brass tubing	19	....	19
Brass and bronze plates and bars	63	....	63
Copper cable and bars	16	....	16
Lead cable covering	6	2	8
Total nonferrous material	105	3	108
Machinery (exclusive refrigeration)	465 (2450 HP)	60 (470 HP)	525 (2920 HP)
Electric motors (exclusive refrigeration units)	4 (295 HP)	5 (191 HP)	9 (436 HP)
Transformers (units)	2	....	2
Switch gear (units)	2	....	2
Instruments and controls	9	3	12
Special equipment (cycle timer, etc.)	3	....	3
Insulation	375	125	500
Welding rod, alloy	3	....	3
Welding rod, carbon steel	24	8	32

NOTE: 25 percent has been added to all items for contingency.

Three Industries Combine Knowledge and Technique to Provide Synthetic Rubber

R. P. DINSMORE, The Goodyear Tire and Rubber Company

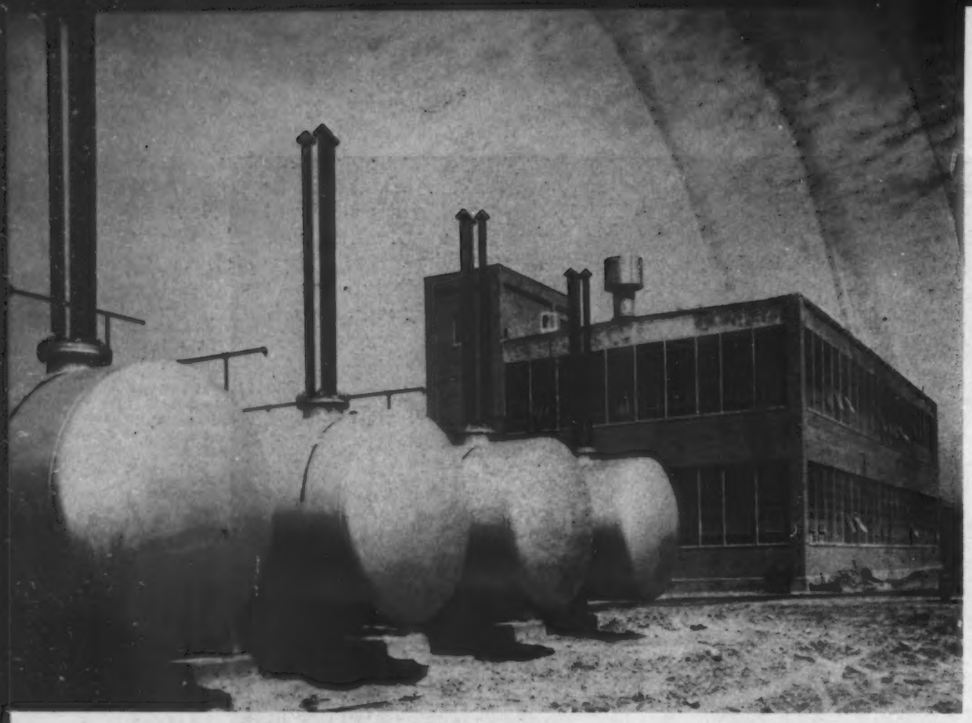
INDUSTRIAL America in its great sweep of mechanized effort, which made it the mightiest nation of all history, became unconsciously, but inevitably, dependent upon rubber, a raw material supplied chiefly from the other side of the globe. The life of not one industry but many has become involved, and perhaps most vital of these is modern transportation, which serves them all.

The close relationship of the petroleum industry to motor vehicle and airplane transportation is too well known to require comment. Hence, arises the paramount interest, which binds oil to rubber. It is a notable fact, therefore, that when the war cut our rubber supply to a mere trickle, the petroleum industry was in a position to aid in the colossal tasks of providing a synthetic substitute.

It is important that we should all understand the task that is before us and the part which each industry must play. The large amount of misinformation which has been disseminated has not only confused the public but has created contention and friction which have only served to retard the movement to provide this vital raw material. Highest authorities have published the fact that even with painful economies there is not enough rubber to last through 1943, and not a shred of credible evidence has been evinced to refute such a statement.

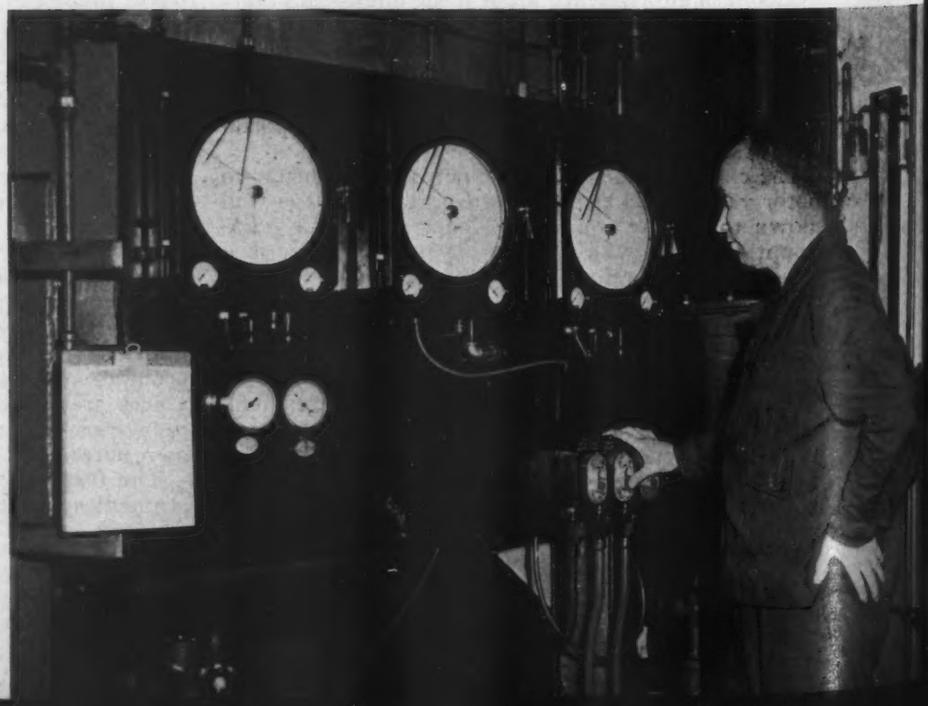
In 1940 the rubber, petroleum, and chemical industries made strenuous efforts to convince the government of the advisability of initiating a government synthetic-rubber industry on a scale sufficient to establish plant designs, operating technique and to provide enough rubber to work out the problems connected with such important products as tires. Their proposals evoked much discussion and received considerable sympathetic attention from many in government circles. Voices were heard accusing these industries of trying to get government subsidy to promote synthetic for their selfish interests. Similar voices are heard today, which say that these same industries are trying to throttle synthetic for their own purposes.

The truth of the matter is that the proposed government synthetic development was purely a matter



Butadiene Storage (left) Outside Polymerization Plant of The Goodyear Tire and Rubber Company.

Weighing Materials into the Reactors (below).

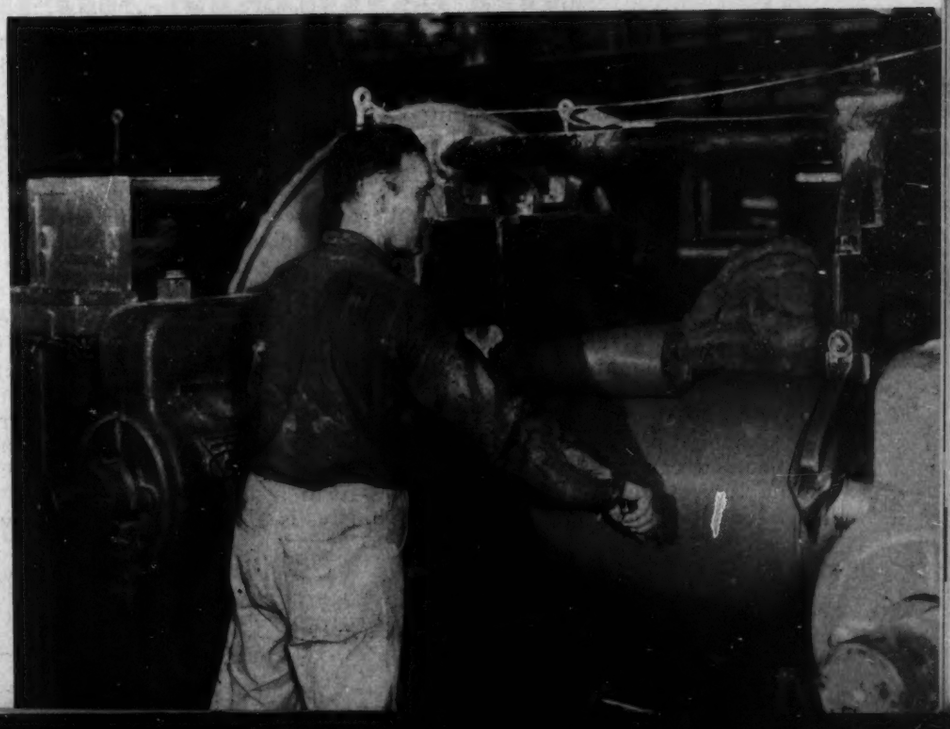


Before Butadiene can be used the Inhibitor, essential in shipping, must be removed. (above.)

Operation of weigh tanks are under constant control (right.)

Product of polymerization (right) is dried constantly on a conveyor belt.

After rolling to near dryness the product is drawn into bins (above) then pressed into cakes (right above) for shipment.



Synthetic rubber is finally rolled into sheeting, after which it is ready for the manufacturing processes into finished rubber materials.

All pictures courtesy The Goodyear Tire and Rubber Company

of national insurance which private industry could not afford to underwrite. Moreover, as a private venture, no legal plan could be evolved which would permit the free industry cooperation necessary to quick development or which would provide the mechanism to try out the product on a large scale through its development stages.

It was not until May, 1941, that small-scale defense plants for rubber polymerization were authorized. Before they were actually constructed in July they were increased to moderate-sized units.

This begining, though small, would have been of inestimable importance had it not been for one unfortunate circumstance. No provision was made for the manufacture of the necessary raw materials by methods which might later be expanded. To understand this statement, it is necessary to appreciate the steps which are taken in the manufacture of the rubber and its raw materials.

Prior to the rubber shortage, synthetic was required in this country chiefly for its oil- and solvent-resistant properties. It was used for such products as chemical-tank linings, gasoline hose, oil gaskets and motor mounts. These wants had been supplied by neoprene and Thiokol, until about two years ago when the Buna type rubbers began to make their appearance in the hands of some of the rubber companies and, later, Standard Oil Company of New Jersey.

These oil-resistant rubbers, of the Buna type, Chemigum, Hycar and Perbunan, were made chiefly from butadiene and acrylonitrile. They were not the most suitable or economical type to use for tire rubber, where oil resistance is unnecessary. Private research had undoubtedly developed many other combinations, some of which probably will prove of considerable ultimate value. However, the emergency requirements caused the adoption of Buna S, a combination of butadiene and styrene, because this rubber offered the best availability, the lowest immediate cost and the highest compatibility with natural rubber.

Styrene, fortunately, already has had commercial development because of its ability to polymerize to form the plastic, polystyrene. It is most readily made from ethylene (petroleum product) and benzol (coal-tar derivative).

Butadiene had never had more than a limited use as a chemical intermediate. It is formed in certain cracking processes and can be separated out as a by-product. This is the way most of the butadiene was obtained or the manufacture of the oil-resistant rubbers and the government had planned to obtain its supply in this manner for its initial defense plants. Before the plants were finished, however, war demands for oil-resistant rubber had become so great that very little butadiene was left over.

In 1941, Shell Chemical Company began erection of a small plant for the production of butadiene. This process contemplated use of chlorine in one of its steps and, before its completion, chlorine was extremely difficult to obtain, even in the quantities required for this relatively small unit. This plant played an important part in the war economy but offered little hope for large expansion, because of the chlorine shortage.

Butadiene can be made in a variety of ways. From petroleum it can be most readily made by cracking butane to form butylene and then the further dehydrogenation to butadiene. This obviously, is the logical method to use in this country. The best process to obtain high yields and high purity on a large scale has not been fully worked out because of the short-sighted policy of relying on by-product materials.

Butadiene also may be made from ethyl alcohol, whether made from grain, sugar or synthetically. Processes have been claimed which carry this through in one stage, which would certainly be an advantage. There seems little present probability that this method could compete with the petroleum method, because of the cost of alcohol, unless the raw material for the production of alcohol (grain, sugar, etc.) were abnormally cheap. Therefore, the only justification for using such a process at this time is based on a surplus of rotting grain and the fact that the plants for making butadiene by this method can be erected more quickly and cheaply.

Rubber Polymerization

Present indications are that not more than 25 percent of the butadiene will be made from alcohol. The rest will come from petroleum.

Buna-S, or styrene, rubber is a hydrocarbon polymer with a chain-like structure which is built up by linking together the two hydrocarbon raw materials, butadiene and styrene. This polymerization process is separate and distinct from the manufacture of the ingredients and has no more relationship to it than the baking of a cake has to the manufacture of flour and sugar. As in cake making, other minor materials must be used to make a successful product.

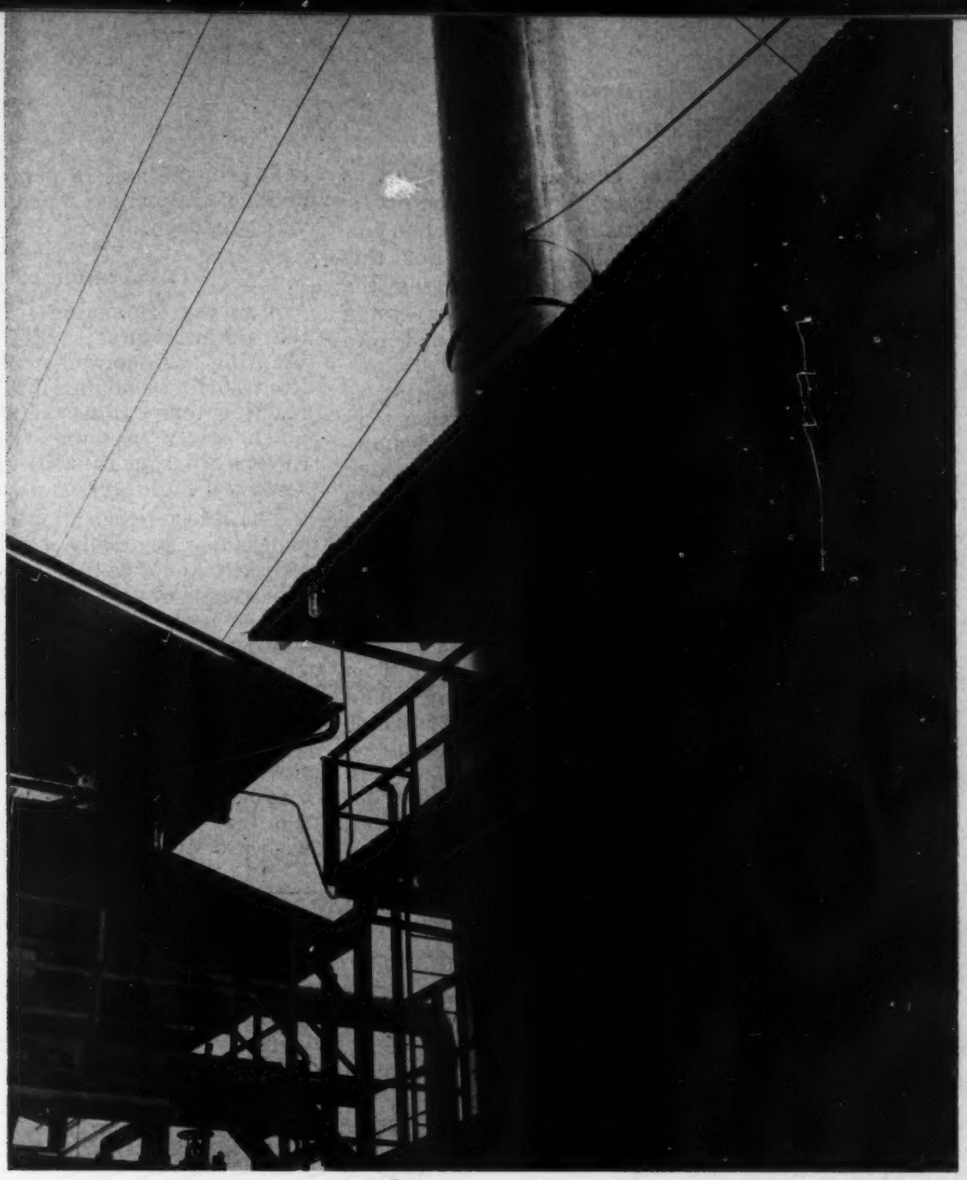
Hence, after the styrene manufacturer has combined his ethylene and benzol to make styrene and the butadiene manufacturer has converted his butane or his alcohol to butadiene, these materials must be supplied to the rubber polymerizer. Styrene is normally a liquid and butadiene is handled as a liquid under pressure or low temperature.

In normal times, it is easier to ship liquids in tank cars than to ship rubber in box cars. Therefore, the first government polymerizing plants were located at points convenient to the rubber manufacturers, who are to operate them, and without special reference to the location of the butadiene and styrene plants. These early plants must be supplied by tank-car shipments. Subsequent plants, because of tank-car shortage, have been located adjacent to butadiene plants, and styrene plants are either adjoining or nearby. Transfer can thus be made by pipe lines.

The rubber polymerizer takes the butadiene and styrene, adds the other necessary ingredients and churns them all up with water to form a milky emulsion.

This mixture is heated under pressure for a number of hours and is discharged as a synthetic latex which then must be coagulated or thrown out of water suspension, washed and dried.

A further word should be added. The plants for making butadiene, styrene and rubber are owned by the government and operated by private companies as agents. The finished material is owned by the government. The government will sell the rubber at such prices and for such purposes as it sees fit. The operator who makes the rubber will obtain no advantage as to its use. Means are being set up to distribute rubber as it becomes available and to disseminate information as to its use in the most effective fashion. All information is available to the government and the government will see that those who need it, have it.



Adaptation of Thermal Cracking to Butadiene Manufacture

IN VIEW of the critical need for synthetic rubber it is essential that a considerable volume of production be developed before the large new units under construction for butadiene manufacture are completed. Fortunately it is possible to convert some existing refining and natural-gasoline units to butadiene production in a relatively short time and with comparatively small need for additional equipment to make the change. Several plans to this end have been worked out.

The Petroleum Conversion Corporation has adapted its "True-Vapor-Phase"-cracking process to the conversion of liquid-phase cracking units to butadiene manufacture by thermally cracking heavy naphtha under high temperature, low-pressure, short-reaction-time conditions. Plans for the conversion of some cracking units in the Southwest have been laid before OPC. It is considered that, in general, not over 10 to 15 percent additional equipment will be required in making the conversion.

Conditions for Making Butadiene

The company has made numerous pilot-plant studies to determine the optimum conditions under which the diene hydrocarbons, including butadiene, may be made thermally from naphtha fractions. A major problem was to prevent the conversion of the naphtha to an excessive yield of aromatics during the heating of the charge to the reaction temperature required. It was observed that the heating curve

(time versus temperature) tended to flatten out as shown by the Curve ABCD in Figure 1 as the necessary reaction temperature was approached, when employing conventional thermal operation. For this reason the amount of time represented along the curve from B to D resulted in appreciable conversion of diene hydrocarbons which had been formed, into aromatics.

The difficulty was overcome by rapid heating of the charge stock to near the necessary reaction temperature and then injecting into the vaporized material a stream of hydrocarbon gases separately heated to such a temperature that the charge would attain the reaction temperature in a few seconds. After this, the mixture of gases and vaporized charge leaving the reaction chamber was quenced to a relatively low temperature. By such procedure the time represented under the curve from B to D could be eliminated in favor of the quite short time BC.

Under ideal conditions for making butadiene from naphtha in this manner, the reaction pressure would be approximately atmospheric and the temperature well above 1200° F. When charging a depentanized casinghead naphtha (hexanes and heptanes) a yield of over 9 percent of butadiene by weight was obtained. Other products included 15 percent butenes, less than 1 percent butanes, 9 percent propene, 1 percent propane and 16 percent aromatic distillate and residue. Only about 2 percent hydrogen and methane was produced.

Adaptation to Existing Units

A survey of existing cracking equipment indicates that the most practicable reaction pressure to use in adapting such equipment to butadiene production is from 20 to 25 pounds per square inch, gauge, with reaction temperature at about 1350° F. To employ much lower pressures would necessarily call for towers of larger capacity than are found on the conventional high-pressure cracking unit.

The charge stock adopted for use in the conversion program is generally a heavy naphtha cut of about 45° API and 250-400° F. boiling range. The current importance of utilizing such a naphtha lies in the fact that in some areas the disposal of the material, or similar fractions, is a problem. Much naphtha of this type has been cracked to make motor fuel or has been blended with light hydrocarbons for the same purpose, but it is obvious that the marketing of motor fuel from some refining regions is at present a difficult matter. By adapting existing cracking units to the manufacture of butadiene from naphtha, this situation may be relieved to some extent, simultaneously with production of the chief ingredient of Buna-type

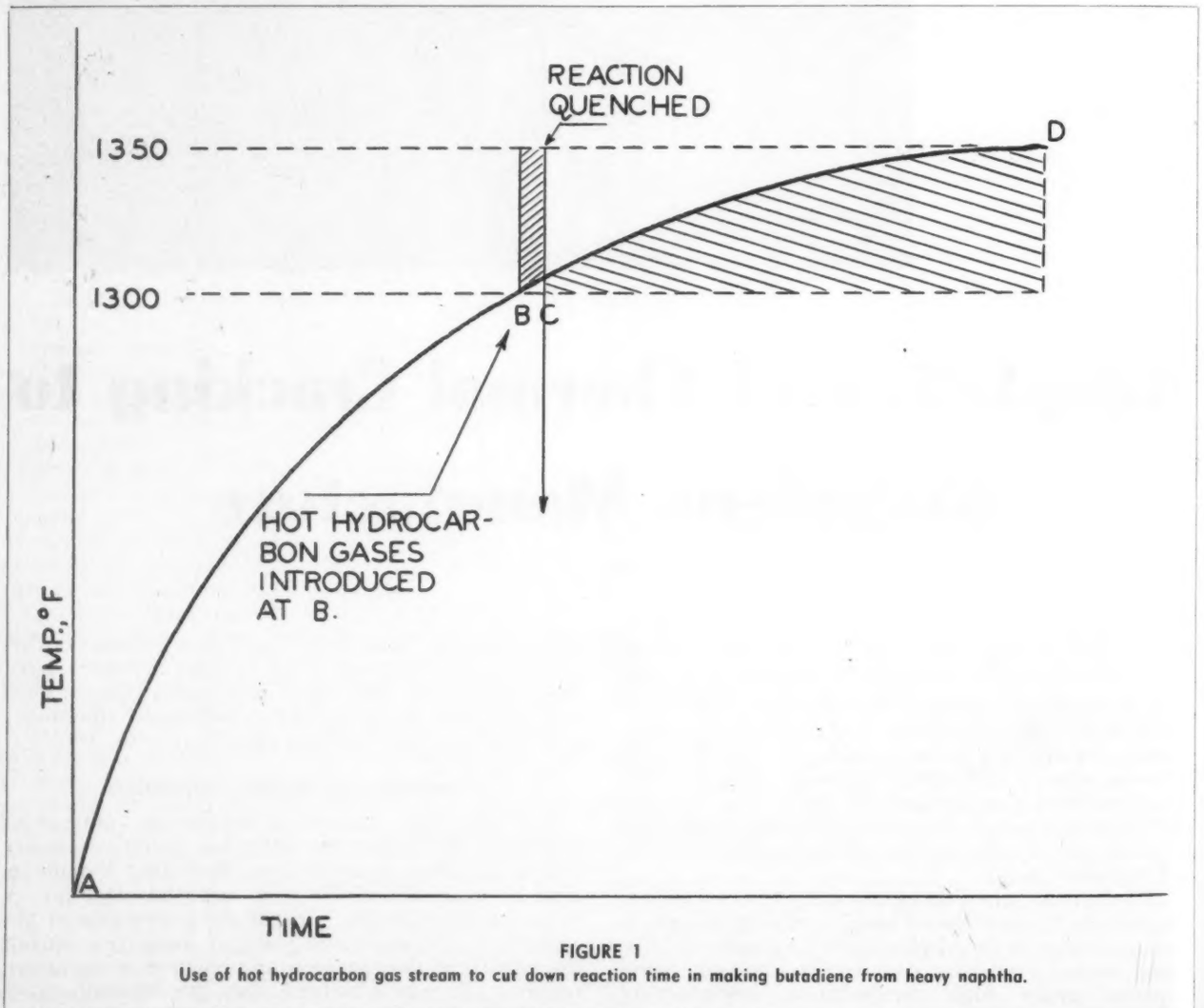
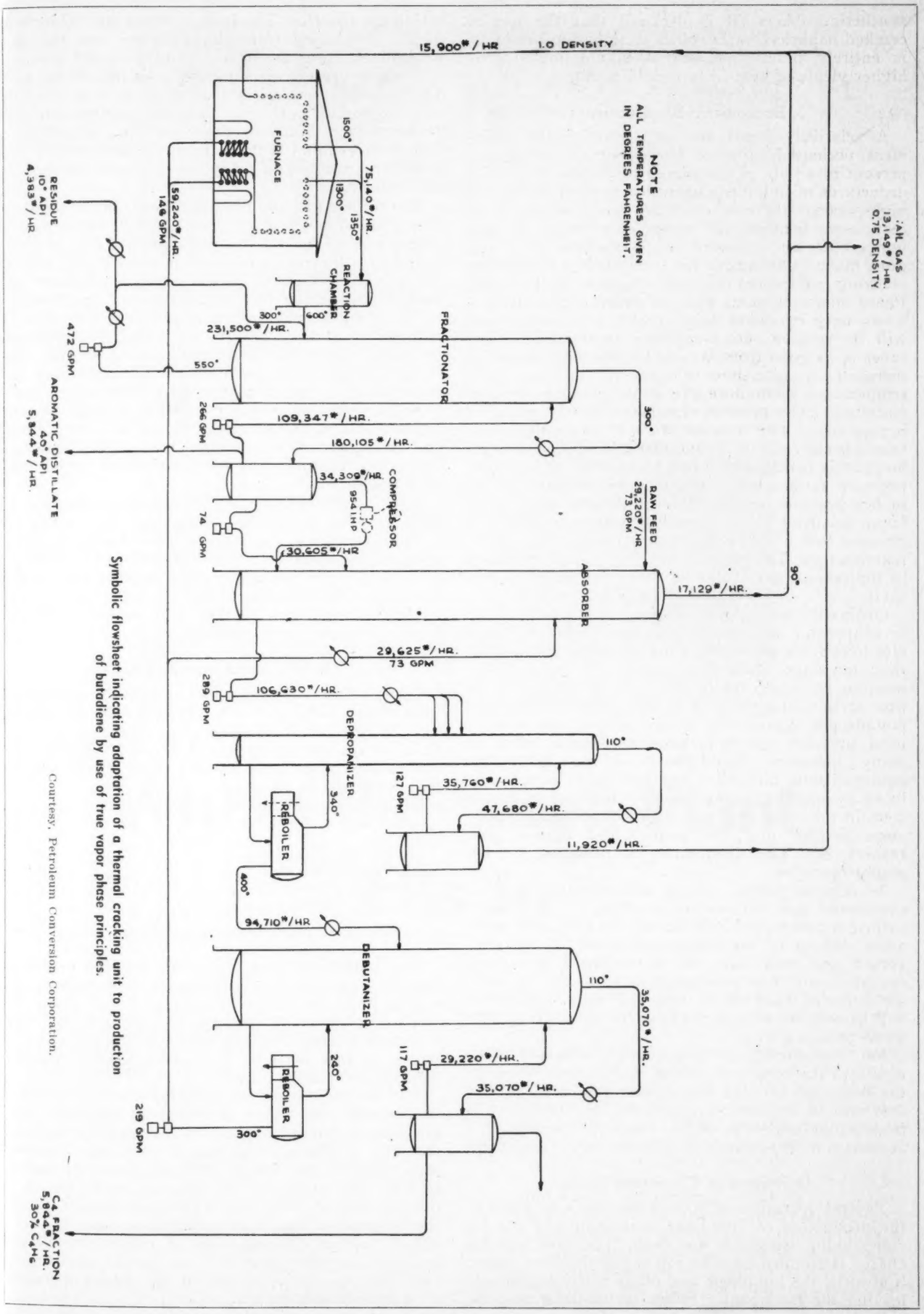


FIGURE 1

Use of hot hydrocarbon gas stream to cut down reaction time in making butadiene from heavy naphtha.



Symbolic flowsheet indicating adaptation of a thermal cracking unit to production of butadiene by use of true vapor phase principles.

Courtesy, Petroleum Conversion Corporation.

synthetic rubbers. It is declared that the use of cracked naphthas, rather than straight-run products, is entirely practicable and it is anticipated that higher yields of butadiene should result.

Equipment Requirements

A relatively small amount of additional equipment, perhaps from 10 to 15 percent of that already present in a unit, is considered necessary. The chief departures of butadiene operation from conventional high-pressure-thermal cracking are the use of a recycle-gas heating coil, low-pressure, high reaction temperature and a short time of reaction. Investigations made to determine the feasibility of converting cracking equipment to principles of True-Vapor-Phase operation show that, in general, existing furnaces have excessive tube surface and some tubes will be removed for butadiene production. Alloy tubes of as good grade as can be obtained should be installed, if not already present, in the high-temperature sections of the vapor- and gas-heating circuits in order to reduce oxidation of tube metal. It is pointed out that because of the low pressure maintained in the coils, it should be feasible to use second-hand alloy tubing which had been retired from high-pressure service but which is perfectly satisfactory in low-pressure service. Because of the short time factor involved, either a small reaction chamber or a transfer line of large diameter will suffiice to give reaction time. The use of an internal refractory lining in the reactor elimiantes the need for an alloy-steel shell.

Ordinarily the existing cracking-unit bubble tower or evaporator will prove sufficiently large in diameter to provide reasonable capacity in the initial fractionation stage. Since the operating pressures on the reaction chamber, fractionator and fractionator reflux accumulator will be in the order of 20 to 30 pounds per square inch, gauge, almost any kind of used pressure vessel is considered acceptable. In many instances liquid-phase-cracking units are equipped with absorbers and stabilizers which may be easily adapted to serve as absorbers and depropanizers in the converted unit operating at gauge pressures of 200 and 300 pounds per square inch, respectively. The debutanizer is designed for 50-pound operation.

As regards pumps, piping and instruments, it is considered that the average cracking unit will have sufficient pumps and instruments for butadiene operation. Piping in the low-pressure end of the converted unit will have to be enlarged to assure operation with low pressure drop up to the compressor suction. This means that the main condensers will have to be rearranged in order to function with a low pressure drop.

For introducing the uncondensed reaction products into the recovery system, compressor power to the extent of ½ to ¾ horsepower per barrel of raw feed will be required. Compressor operation here is from gauge pressures of 20 pounds per square inch at suction to 200 pounds per square inch at discharge.

Operation of Converted Units

Typical operation of a cracking unit converted to the production of butadiene is indicated in the accompanying simplified flowsheet. The raw naphtha charge is pumped into the top of the absorber, where it absorbs the butadiene and other reaction products leaving the fractionator reflux accumulator and entering the absorber. The feed, together with absorbed gases, is pumped from the absorber into the depropanizer. Here, the propene and the small amount of propane present are removed from the stream and are recycled, together with light gases from the top of the absorber, to the recycle-gas coil in the furnace. Depropanizer bottoms flow to the debutanizer. Butane-free liqiud is taken from the debutanizer reboiler and pumped as charge to the vaporizer coil in the furnace.

The recycle gas and the vaporizer transfer temperatures are about 1500° F. and 1300° F. respectively. The combined recycle gas and vaporized charge mixture enters the reaction chamber at 1350° F., where reaction occurs within a few seconds. Reactor effluent is quenched by the addition of fractionator bottoms, although a portion of these bottoms is pumped to storage as 10° API fuel. Fractionator overhead vapors are condensed and flow into the fractionator reflux accumulator. Condensate from the accumulator is largely returned as reflux to the fractionator, and a portion is pumped to storage as aromatic distillate. Accumulator vapors are compressed and discharged, as is also some accumulator condensate, into the absorber, the function of which has been described.

The C_4 hydrocarbons, which include the butadiene, pass from the top of the debutanizer, are condensed and are pumped to the butadiene purification system, where C_4 hydrocarbons are separated from the butadiene. The purification system utilized is that of the Standard Oil Company (New Jersey), and is described in the article of this issue dealing with the Houdry butadiene process.

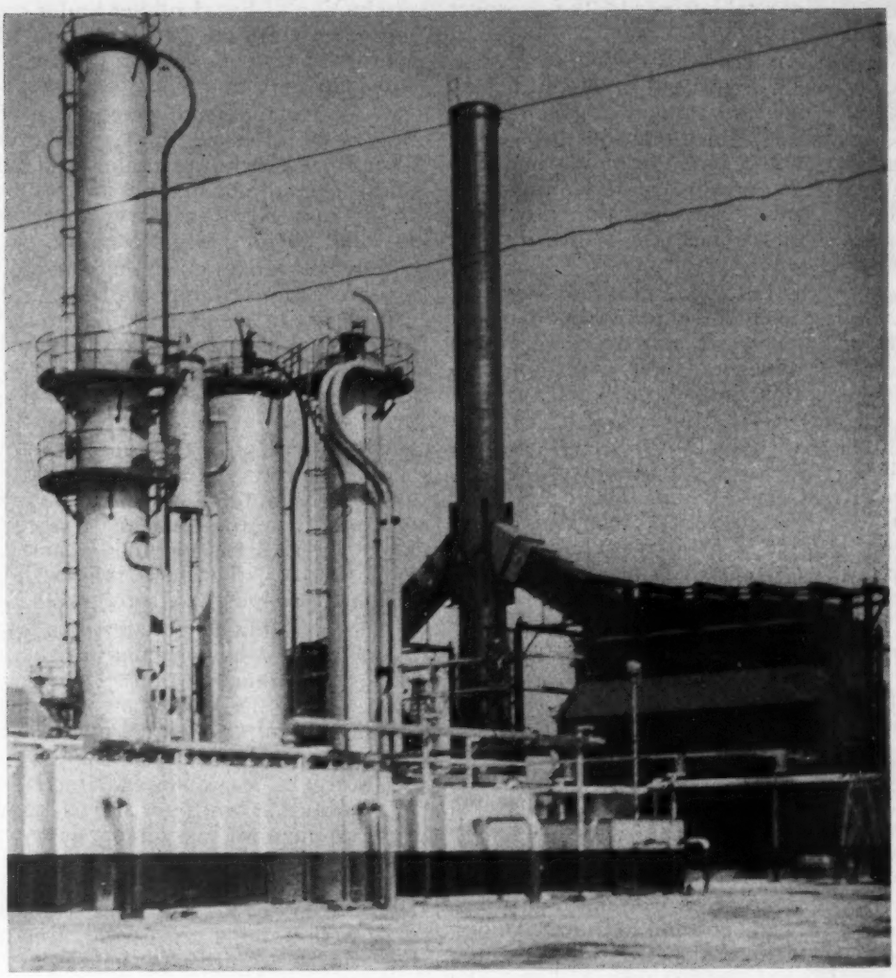
Yields From Converted Unit

On the basis of pilot-plant runs it is considered that when charging a 45° API, 250-400° F. boiling range virgin heavy naphtha and subjecting this material to reactor conditions of about 25 pounds per square inch gauge pressure and 1350° F., the following yields will be obtained:

	Weight Percent
C_3 and lighter gases	45
C_4 cut (30% butadiene)	20
Aromatic distillate	20
10° API residue	15
	100

The butadiene yield, therefore, will be 6 weight percent, based on the fresh charge. It is pointed out that an important fact is that the C_4 cut also contains 65 percent butene, 50 percent of which is isomer, and 5 percent butane. The butene content of the cut is a source of raw material for production of polymer gasoline or aviation alkylate.

The aromatic distillate contains about 50 percent of benzene and toluol in equal proportions. The problem of purifying these is lessened by the fact that the distillate, after recycle cracking, contains practically no paraffins. Need for a solvent-extraction step in the production of nitration-grade toluol is thus eliminated. Attention is called to the fact that in the by-product gas is a considerable amount of C_2 and C_3 olefins. These gases, if needed, would be available for use, inasmuch as the by-product-gas yield exceeds the fuel needs for the overall operation by a considerable margin.



Where the Small Plant Fits In

THE question, "where does the small plant fit in?" frequently asked as the refining industry enlarges into chemical processing, is in itself evidence that some doubt its future existence.

What is ignored is that the industry now is dealing with processes rather than plants. Since the research responsible for processes so frequently comes from larger corporations there is acceptance that plants will be those of the larger corporations.

The proper conclusion is that a plant may be small in capacity in chemical processing; it can not be small in technology.

It is not reasonable that the small plant as it has existed will continue. Straight-run gasoline, kerosine, furnace distillate and fuel oil will not be sufficient. Even its motor fuel will not match the requirements of motors built to use 100-octane fuel.

Another mistake is that of considering synthetic rubber the only new product from petroleum. If that were the end rather than the beginning of petroleum processing, small plants could withdraw. Even here, however, recent months have established that plants smaller than first considered can have a share in butadiene production. This has not come to the point where daily capacity of 1000 barrels is sufficient to provide enough lighter hydrocarbons for economical butadiene manufacture. Still the rush toward more butadiene at an earlier date involves plants of no more than 10,000 barrels daily capacity.

Tonnage figures for synthetic rubber are impressive but misleading. A million tons of material each year leaves the impression that here is another substantial need for crude oil or its gases. When calculation reveals that less than one percent of present refinery throughput will supply all the petroleum

ingredients for synthetic rubber needs, the prospect is less attractive.

If butane alone were used as the starting material, 50,000 barrels each day would supply butadiene in larger quantities than any total of finished Buna S rubber now anticipated. Since one fourth of butadiene requirements will come from agricultural sources, the final effect on petroleum refining from a volume standpoint leaves it evident that providing ingredients for synthetic rubber is not sufficient for distribution to all refining plants.

In its early stages the butadiene program was considered on a basis of 25,000-barrel limitation on plant capacity. A charge of that size was accepted as the lowest that could provide sufficient gases for economical dehydrogenation into butadiene.

Smaller plants are now being adapted for two reasons. Additional processes have been found effective while immediate need for butadiene has readjusted economic considerations. The catalytic Houdry process now is part of the program and going into plants of the 15,000-barrel class. Vapor-phase cracking such as the TVP process is being adapted to thermal-cracking units, which will be charged with gasoline under high temperature and low pressure. Adaptation of these processes is discussed in this issue of PETROLEUM REFINER. Another is the Thermfor Catalytic Cracking unit, which is adaptable with thermal cracking.

In each instance the saving in critical steel products is a factor in economic considerations. These represent what has been learned since it became necessary for petroleum refining to assume the leading role in synthetic rubber ingredients. Further inclusion of smaller plants in the production of butadiene depends on its success as currently outlined, plus the attitude of the rubber administrator. Among the recommendations of the Baruch committee is the provision of an additional 100,000 tons of butadiene through conversion of existing plants.

Status of the butadiene program changes rapidly. The compilation below was taken from sources as late as October 1:

	Butadiene Plants Building or Authorized (Tons)
From Oil	
Atlas Refining Corporation	12,000
Cities Service Refining Company	55,000
Humble Oil & Refining Company	30,000
Neches Butane Products Company	100,000
Phillips Petroleum Company	50,000
Shell Chemical Company	30,000
Sinclair Rubber, Inc.	50,000
Southern California Gas Company	25,000
Standard Oil Company of Louisiana	21,200
Sun Oil Company	15,000
Conversion of small plants (not announced)	20,000
From increased yield through higher temperatures in plants building	93,500
Total from oil	501,700
From Alcohol	
Carbide and Chemicals Corporation	242,000
Total all sources	743,000
Recommended	
From Oil	
Conversion of existing small plants	100,000
From Alcohol	
Additional plant	27,000
	127,000
Total authorized and building	870,000

The total does not include 132,000 tons of annual production of Butyl rubber under construction whose ingredients are only 2 percent butadiene and 98 percent iso-butylene. All of this will be provided by subsidiaries of Standard Oil Company of New Jersey.

Hope for the small plant in the future lies in the prediction of Wright W. Gary, elsewhere in this issue, that the future refiner will be a specialist. He may select one or more of the products now possible from crude oil as primary objectives, leaving motor fuel and burning oils secondary.

Solvents are an example. The paint industry is but one to which refining may be directed. A few concerns have held this relationship in the past. Chiefly, however, the coal-processing industry has provided the solvents for paints and lacquers. It has long been known that oil is as rich in solvents as coal. Now the processes are at hand for recovery or conversion.

Plastics promise to become the outstanding material of the future. These may enlarge the demand for alcohols to a total beyond capacity of coal-tar distillation or processing from agricultural products. Since the alcohols are finally established from petroleum sources, the small refining plant may find its primary product from processing to this end.

The possibilities get down to such items as pure hydrocarbons for pharmaceuticals, dyes, even perfumes. In some of these requirements may be so limited that the small plant will have advantage over the larger units.

None of these will be handed to a plant simply because it is small in capacity. None will be denied the institution whose technical knowledge and operating ability are in keeping with what the products demand. The laboratory will play a more important role in refining than it has in the past. In addition to control over finished materials, chemistry must be used to determine processing. Men of technical training will be required on the yard.

The small plant of the future will require a change in sales viewpoint. Instead of striving to gain a profit by selling a few common products in a competitive market, the special hydrocarbons will involve selling perhaps to one customer, or a few customers, elsewhere in the chemical industry.

Here the question arises as to where a small plant can have advantage of research and processes by which pure hydrocarbons are recovered. The question is identical with that of 20 years ago when thermal cracking was introduced. It threatened smaller plants. Soon, however, processes were being offered with the result that cracking is now as economical for the small plant as for the large one. Later polymerization came along and even more quickly was available regardless of plant capacity.

Only a turn of affairs that will remove patents, licensing and consultation can keep the newer petrochemistry out of the common channels of business. Here the trend is the reverse. Urgency of war products has for a limited time converted patents almost into common property. Time only will tell whether, after the war, this will be withdrawn. It may be that process owners will not desire to withdraw it.

The only thing happening to refining now is change, something that is common in any industry. Two years are like 20 years under war pressure. Management for a small plant must recognize the difference in time. Furthermore management, regardless of plant capacity, must find its place in a changing condition instead of waiting to see what effect the change brings.

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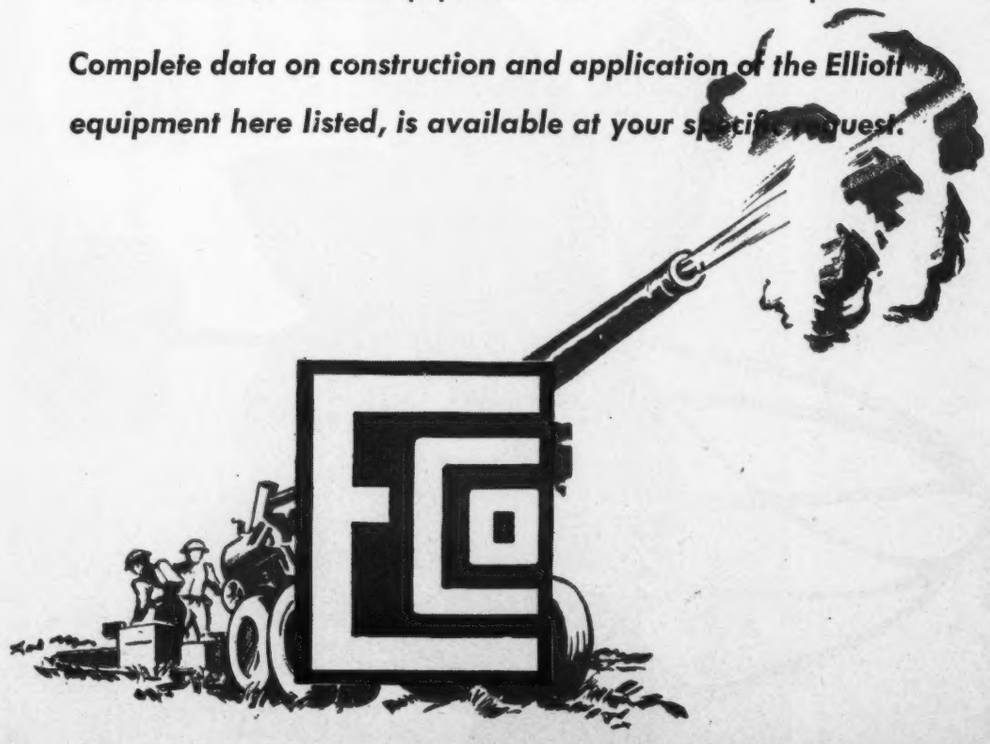

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Orchids were removed from the Kew gardens in London so the Hevea seed could be sprouted and the British Empire expanded in the Far East.

Chemistry Converted Rubber into Usable Material

RUBBER was conquered by chemistry and made to serve mankind. The 32,000 products fashioned from the latex of the Hevea tree came into existence after Charles Goodyear left a combination of gum and surphur on the stove overnight and thus solved a problem, which had defied scientists for more than 300 years.

Before the Japanese conquest it was common for a million long tons of crude rubber to come out of the Malaya peninsula and the Netherlands Indies. Half of it reached the Unted States where so much of it went into tires that a man seldom recalled his first contact with rubber in a teething ring and finally waited for an upper plate of rubber content. It was the backbone of the British and Dutch empires in the Far East, with 8,000,000 acres in plantations, 2,700,000 persons employed, and $2,500,000,000 invested.

Such was the magnitude of an industry, transplanted to the area in 1877 after a shipment of Hevea seeds had gone from Brazil to the Kew Gardens in London for sprouting. It is this industry which petroleum refining, chemistry and rubber polymerization must supplant in two years. Its history may have little bearing on what is taking place in the countries that are shut off from rubber. Still it is interesting to note a few incidents in the romantic and slow progress by which a natural product finally expanded into wide usage and to contrast it with the speed at which it must be duplicated.

Columbus is credited with being the first white man to be fascinated by rubber when he found natives of Santo Domingo bouncing a ball against a wall. Whether he took samples back to Queen Isabella or not, the word got to Europe that a material existed which would bounce, a quality no other material had. Cortez and his conquerors were entertained by the soldiers of Montezuma, who played a game with a ball "from the gum of trees that grow in the hot countries."

The French Academy of Science sent LeCondamine to South America to gain knowledge of how natives worked the latex into solid form. This was in 1736, more than 200 years after rubber samples had been sent to Europe. All he learned was that latex was collected and held over a fire to cure with the result that a ball was the simplest of products to fashion. Over moulds they poured the liquid, cured that layer, applied another layer and cured it and had a crude type of footwear. Whatever the product, its physical characteristics changed with the temperature.

It was not until 1770 that the product got a name. Joseph Priestley, the English scientist, discovered its usefulness in removing a pencil mark from a piece of paper and the cured latex of the tree

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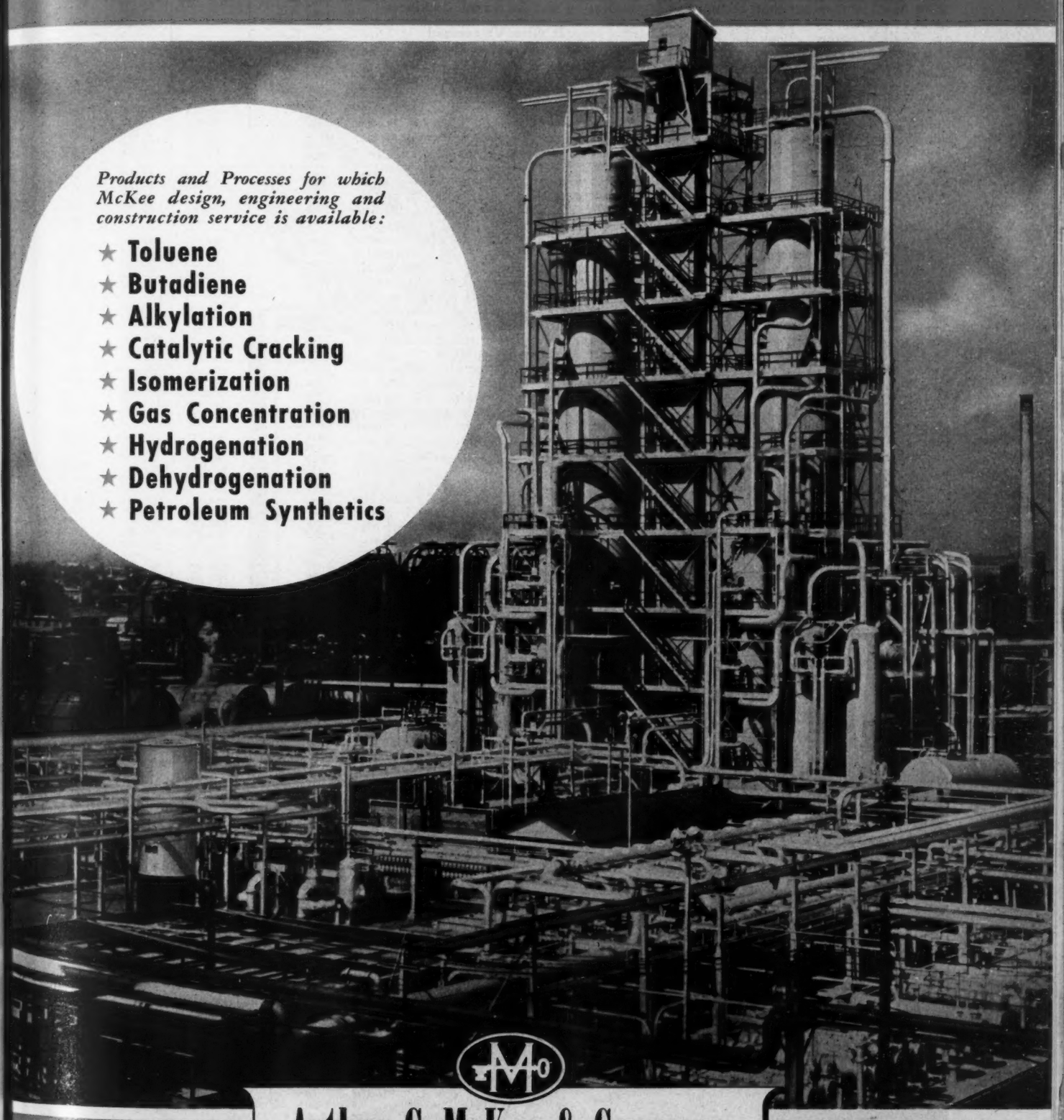

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Hevea of the Amazon valley and other hot climates became rubber.

Long before rubber became a satisfactory material for wearing apparel, Samuel Peel, another Englishman, took out a patent, "a method of rendering perfectly waterproof all kinds of leather, cotton, linen and woolen cloths." Statement of a claim rather than accomplishment of the claim is the requirement for an English patent. Peel did discover that latex would dissolve in turpentine.

A waterproof garment had to wait for Charles Macintosh. This canny Scotchman was a practical chemist. He worked some coal-tar products down to light distillates for which he could find no market and wondered if he had a solvent for rubber. His experiment was successful in that the two made a pliable gum, which he placed between two layers of fabric and out of that came the mackintosh. The gum still was brittle in winter and foul smelling in summer, but it protected men from the elements, except where the garment was stitched. Evidently his product ran into evil days and he charged the medical profession in these words, "the medical faculty having lent their aid to run down the use of waterproof (apparently from having found it a decided enemy to their best friends—colds and catarrahs) the use of the article in the form of cloaks, etc., has of late become comparatively extinct."

Thomas Hancock, a London coachmaker, adapted crude elastic to keeping gloves tight at the wrist and fashioning shoes which would be put on or removed without lacing. His losses in cuttings prompted an experiment in grinding with the unexpected result that under mastication they became a mass and ready for cutting into strips. He and Macintosh formed a partnership.

In the United States Edwin M. Chaffee moved a step ahead by compounding other materials with rubber. Like others in Europe he looked on rubber as a waterproofing material and he found a combination of rubber, lamp black and turpentine such an improvement over other preparations that he incorporated the Roxbury India Rubber Company in 1833.

None of this, however, converted rubber into a satisfactory material. Turpentine made it pliable but hastened deterioration and increased stickiness.

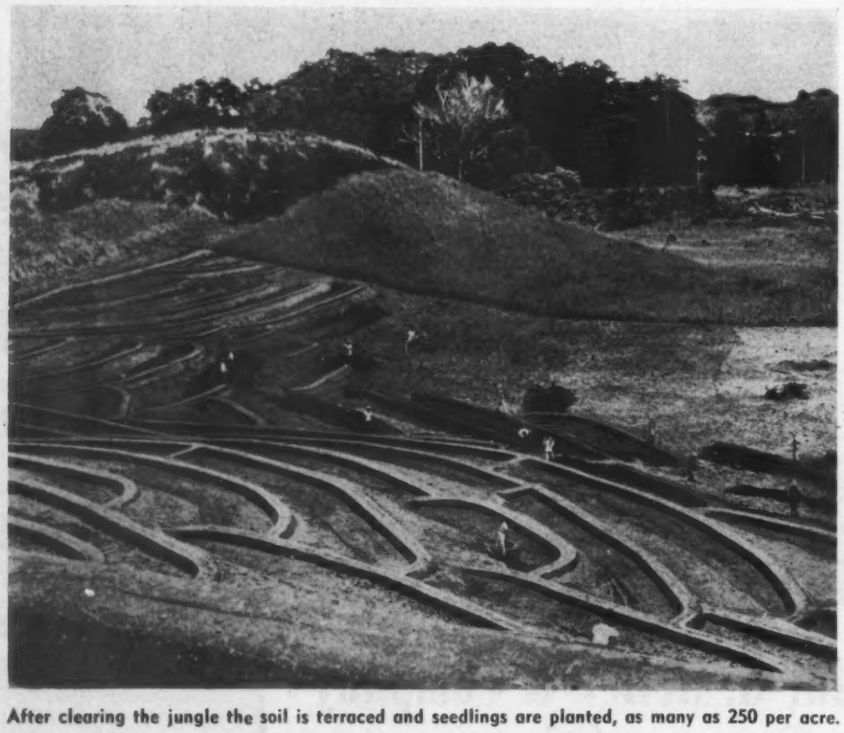
It Gets Vulcanized

The entry of Charles Goodyear reads like romance. He bought a life preserver manufactured in the Roxbury plant and returned within a few days in the hope of selling an invention, a valve for inflating the rubber bag. Then he learned that the Roxbury India Rubber Company was under the pressure of merchandise returned because rubber could not be made to withstand the elements. Instantly he turned his attention to rubber and the answer finally was vulcanization.

As a youth Goodyear wanted to enter the ministry. Instead he became a storekeeper in Philadelphia and would not retreat into bankruptcy when faced with failure. His debts were his own responsibility, although he spent days in jail for all of his determination and explanation. Even this did not halt his fanatical interest in rubber.

His first success was with nitric acid, which affected only the surface, still he had the basis of a patent and income from licenses allowed him to move to Roxbury to be near the rubber plant. There he met Nathaniel Hayward, another searcher after the secret of rubber. Hayward had dusted rubber with sulphur and left it exposed to the sun. Goodyear bought this patent. Again the plant went into operation and goods made of sulphur-cured rubber went into trade. Again they came back, for this curing left rubber greedy for the atmosphere and victim of the weather. Financial disaster was the answer and the rubber secret was still unsolved.

Courtesy, United States Rubber Company



After clearing the jungle the soil is terraced and seedlings are planted, as many as 250 per acre.

Annual World Absorption of Crude Rubber
(Long Tons)

YEAR	World	U. S. A.	Percent U. S. to World
1890	.....	13,500	.....
1891	.....	15,300	.....
1892	.....	14,700	.....
1893	.....	15,900	.....
1894	.....	13,900	.....
1895	.....	16,700	.....
1896	.....	13,700	.....
1897	.....	17,300	.....
1898	.....	18,600	.....
1899	.....	22,700	.....
1900	52,614	20,308	38.60
1901	52,439	22,954	43.77
1902	49,722	21,244	42.73
1903	56,727	23,240	40.97
1904	64,122	26,089	40.69
1905	70,172	27,021	38.51
1906	74,560	28,640	38.41
1907	77,431	28,817	37.22
1908	74,282	32,403	43.62
1909	86,209	39,789	46.15
1910	99,355	42,210	42.48
1911	99,072	41,728	42.12
1912	120,727	55,937	46.33
1913	129,606	51,987	40.11
1914	117,341	62,265	53.06
1915	155,571	98,990	63.63
1916	185,735	117,611	63.32
1917	215,377	157,371	73.07
1918	227,754	160,000	70.25
1919	304,983	215,000	70.50
1920	294,259	206,000	70.01
1921	277,623	177,772	64.03
1922	408,216	301,499	73.86
1923	445,628	319,422	71.68
1924	466,319	328,769	70.50
1925	557,847	388,481	69.64
1926	544,307	366,149	67.27
1927	597,119	373,000	62.47
1928	676,615	437,012	64.59
1929	805,500	467,408	58.03
1930	712,900	375,735	52.71
1931	684,000	350,000	51.17
1932	689,700	332,000	48.14
1933	822,300	401,079	48.78
1934	919,700	453,223	49.28
1935	936,400	491,544	52.49
1936	1,037,900	575,000	55.40
1937	1,095,100	543,600	49.64
1938	933,600	437,031	46.81
1939	1,076,217	592,000	55.01
1940	1,099,333	648,500	58.99

Compiled by the—
Rubber Manufacturers Association.

Source:
World Absorption: 1900-1924—U. S. Dept. of Commerce.
World Absorption: 1925 to date—I.R.R.C.
U. S. Consumption: R. M. A. files and monthly reports raised to 100 percent based on Dept. of Commerce annual surveys.

There are several versions of the actual discovery of vulcanization. Goodyear, knowing that sulhpur and heat had some influence on rubber, can not be styled a success because of accident. One version is that he left the combination overnight on a stove and found it charred the next morning. However it came about, Charles Goodyear made the outstanding discovery in all rubber development. By controlling amounts of sulphur and temperature of heat he had found the answer to making rubber the servant of mankind.

Although his discovery was of value beyond dollar valuation, strangely enough he never profited from the 200 patents issued in his lifetime. His vulcanization patent was not issued until 1844, five years after its discovery. Meanwhile others had claimed the discovery and the result was long and expensive litigation. He died in 1860, in debt $200,000.

Until vulcanization made rubber useable, wild growth in the Amazon valley was sufficient for all needs. As an es-

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When trees are a year old buds from trees of known productive ability are grafted to assure high yield.

tablished servant of mankind its quantity drew the attention of governments, financiers and promoters. Between there was geographical conflict but Ceylon, Malaya, Sumatra and Java finally came to dominate the plantation growth of natural rubber.

It Gets Moved

Rubber looked attractive for plantation propagation in England and the suggestion of transplanting Hevea brasiliensis to the Eastern colonies caught the fancy of the East India Company. After failure with several batches of seed, Sir Joseph Hooker suggested that Henry Wickham, a rubber trader in the heart of the Hevea country, be commissioned to provide seed in quantity. It so happened that the profitable proposal reached him just before an English steamer was left without return cargo at one of the Amazon ports. Accordingly, he chartered the vessel and marshalled native labor in collecting 70,000 seed, which were packed in banana leaves and loaded for quickest possible arrival.

He still faced failure, for the boat had to clear from Para and Brazilian authorities frowned on attempts to transplant the Hevea tree, promising source of income. Wickham knew intentional delays could rob the seed of germination. So the cargo was pictured as botanical specimens for Her Majesty's royal gardens at Kew and the boat was released under that impression.

A special train met the boat at Liverpool and even the orchid houses and propagating sheds of Kew gardens were cleared for getting the 70,000 seeds in soil. Only 2,397 seeds germinated. But in August, 1876, 1,919 young Hevea plants were shipped to Ceylon to become the starting point for the rubber industry of the Far East.

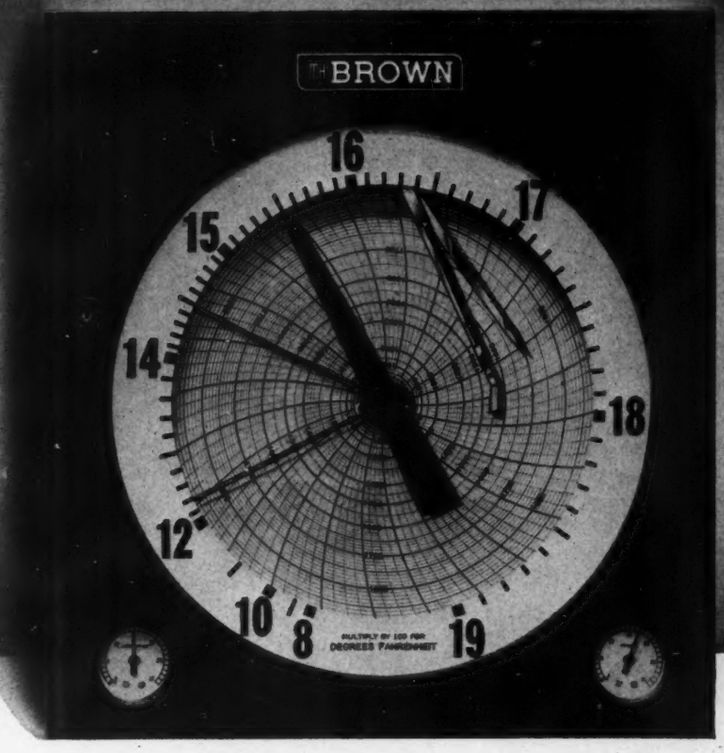
It was 30 years before the Far East made a contribution to natural rubber, shipping only four tons. That period was one of unbridled promotion, speculation and price manipulation. The lure of profit from rubber plantations was perfect for the preparation of a prospectus. In both the United States and Europe corporations were formed, stock sold and feeble efforts at rubber culture started in Africa, Central America, Mexico and some of the tropical islands. The bicycle tire plus the vulcanization of rubber had stimulated demand and the wild trees of the Brazilian jungle carried the load despite the promises of profits from growing rubber.

Para gum, best grade from Brazil, went to $1.50 per pound in 1905. It continued upward until 1910 when the price was $3.06 per pound. In immediate profit the Brazialian industry was taking advantage of failure of the plantations. The higher prices, however, were a stimulant in the Far East, where climate, low-cost labor and efficient colonization were best suited to rubber

Courtesy, the B. F. Goodrich Rubber Company

When a tree is seven years old it yields to the knife and gives up its latex. Each second day a fraction of an inch of bark is removed, while healing goes on above.

The Instrument of Tomorrow



WORKING *Today* IN THE WAR INDUSTRIES

THE Brown *"Continuous Balance" Air-o-Line* Potentiometer Controller is the culmination of more than three-quarters of a century of experience in building industrial measurement and control instruments.

The experience of the past combined with the demands of today have resulted in a new potentiometer air-operated controller that will meet the needs of many future years.

In this radically new potentiometer controller a *"Continuous Balance"* Unit takes the place of the galvanometer used in the conventional mechanical-type potentiometer employing a periodic or cyclic mechanism.

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The Brown Circular Chart *Air-o-Line* Potentiometer Controller brings to industry, for the first time, the ideal synchronization of measurement and control for temperature processes.

In the synthetic rubber war program engineers have approved this instrument as the ideal controller for the difficult fractionating problems in the manufacture of butadiene.

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Outstanding features such as: Control Unit — Throttling Range Dial — Automatic Reset Dial—Booster Pilot Valve—Control Index Knob—Direct and Reverse Action—Compression Type Fittings—Control By-Pass Panel—Balancing Motor—Slide Wire—Pen Arm Release—Chassis—are fully described in Bulletin 15-4. Write for it.

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production. The higher price made the investment in plantations attractive and planters had 60,000 acres in the Far East.

From the 4 tons of 1904, shipments jumped 145 tons a year later. Planting continued, production mounted, until in 1914 when the Far East surpassed all other rubber sources — 72,000 tons against 37,000 from Brazil and 12,000 from all other sources. By 1920 plantation rubber had established its supremacy and was three fourths of world supply. It was more than 98 percent of the supply when shipments were halted in 1942.

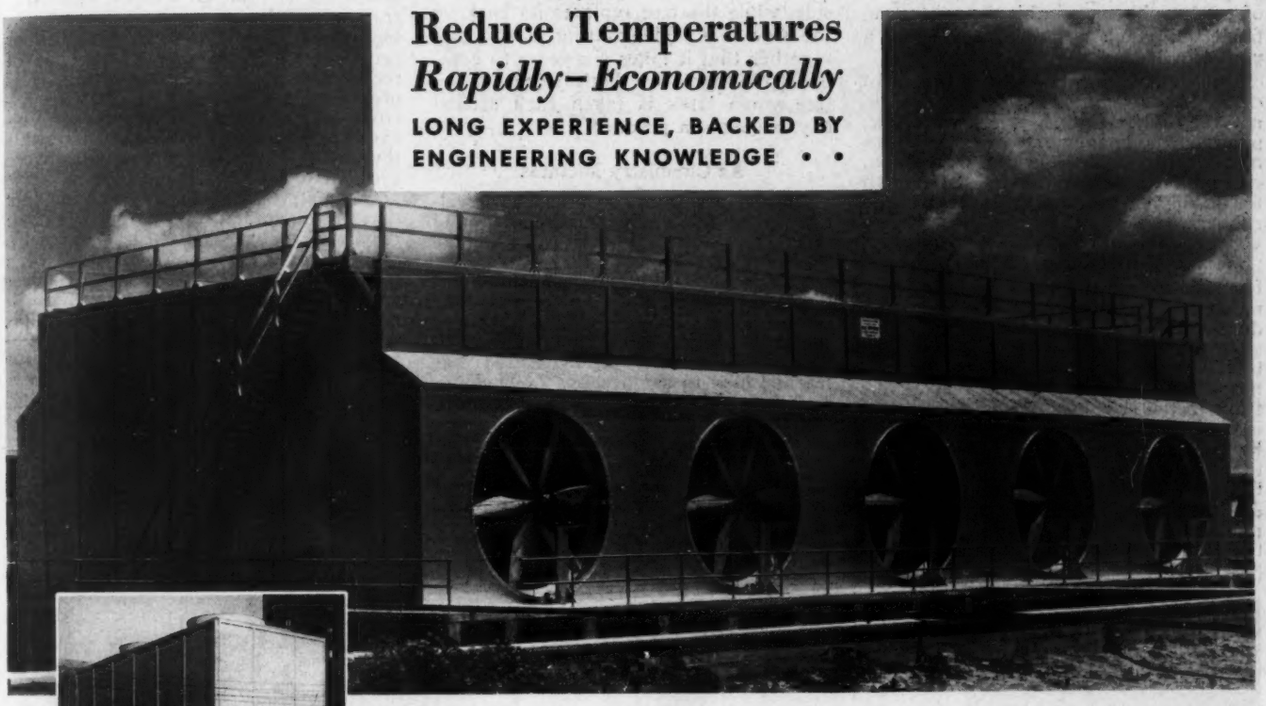
Plantations Triumph

Meanwhile prices went down as plantation rubber increased. By 1921 it was down to 11½ cents a pound. In time the Stevenson plan for control of rubber prices was invoked and this time it was the English plantation owner who profited temporarily from a price in excess of $1 per pound. Plantation owners of the nearby Dutch East Indies had no part in this price-control effort and they profited from English price con-

After weighing in latex must be processed, first for removal of water and other foreign materials, then dried.

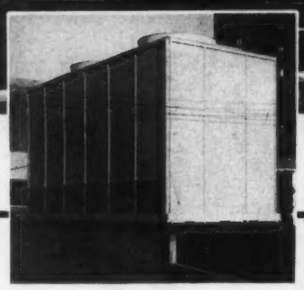
Weighing stations are dotted over the plantations

LILIE-HOFFMANN *Cooling* TOWERS



Reduce Temperatures *Rapidly–Economically*

LONG EXPERIENCE, BACKED BY ENGINEERING KNOWLEDGE • •



The hundreds of Lilie-Hoffmann Cooling Tower installations throughout the country are a vast laboratory for study and research by L-H Engineers. Many of these have been in operation for over 30 years, during which time they have been under our consistent observation. It is only natural that the life and efficiency of Lilie-Hoffmann Cooling Towers can be accurately predetermined—a vital factor where many years of economical service are to be expected.

Selecting the correct type of cooling tower for any installation requires a thorough study of all the advantages of each particular type.

We manufacture *all* types of Cooling Towers to suit every need—Mechanical Induced or Forced Draft—Atmospheric Deck—Combination Spray and Deck—in capacities ranging from 10 to 75,000 GPM.

And because we *have* made and *do* make all types—the specific recommendation of our engineers in every case is unbiased. The installation best suited to *your* needs is the one you will receive.

Call us in on your Cooling Tower problems.

LILIE-HOFFMANN COOLING TOWERS, INC.

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OLDEST IN EXPERIENCE

trol just as the early English plantations had profited from arbitrary price control in Brazil.

The final result was another instance to prove that statutes and agreements can not alter economic law and the price of crude rubber again hit the toboggan, finally to reach a low of 2½ cents a pound in 1932.

Price fluctuations whether by control or by free economy had two effects on natural rubber. When prices were low, plantation management was forced to reduce costs; when prices were high, chemists were justified in striving to finish rubber products with less crude rubber.

Horticulture reduces cost by increasing yield. A plantation Hevea tree starts from a seed but grows from a bud, taken from a tree of known high productive ability. This is chiefly responsible for the increase from 250 pounds to 1,250 pounds per acre. A rubber tree becomes productive at seven years. Contrary to the popular impression its latex is not the sap but is contained in a layer between the bark and the body of the tree. Tapping a rubber tree is not boring a hole as in collecting maple syrup. Instead the workman cuts away the bark at an angle around one side of the tree. This calls for skill since the body of the tree suffers by cutting too deep. The latex drains down this cutting into a cup. The next cutting is slightly below the first, a fraction of an inch. When a space has been cut away the procedure is followed on the other side, while the tree replaces its bark on the side first. The cutting is so close together that it takes six years to complete the cycle on both sides of the tree when latex is taken each second day, a common practice.

As Chemistry Dictates

American rubber concerns had developed extensive holdings and contributed much to the culture and care of the Hevea tree previous to 1941.

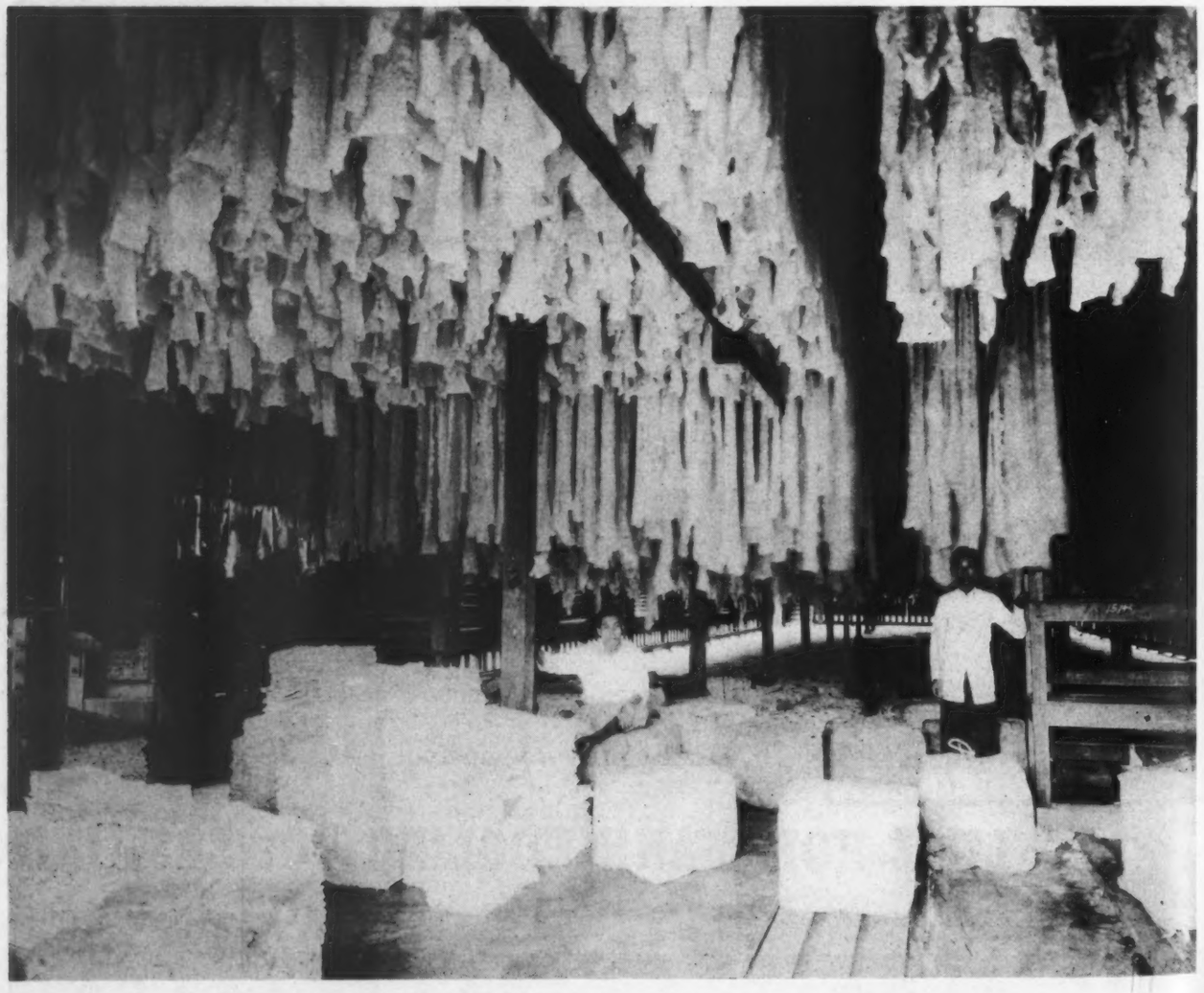
Few rubber products are the combination of latex and sulphur of simple vulcanization. Other chemicals account for 20,000 miles instead of a few hundred in a casing. The chemist has learned how to use perhaps 2,000 chemicals in making the 32,000 rubber products. Carbon black and zinc oxide are major ingredients in automobile casings.

Rubber may be air-tight or a sponge; water proof or absorbent; wear-resistant or of wear responsive; as insulation or as a conductor; elastic or fixed. Chemicals and processing determine the final product and this has been the foremost contribution of the United States.

The science is now so extensive that one of the major sections of the American Chemical Society deals with rubber chemistry. Chemistry was introduced by Arthur H. Marks, who was responsible for the alkali process for separating cotton fabric from rubber products, the foundation of the use of reclaimed rubber in manufacture. His organized research also led to the discovery of organic accelerators of vulcanization by George Oenslager. By this the poorer grades of natural latex were brought to higher standards.

Chemistry is responsible for the fact that in manufacturing 33.5 percent of reclaimed rubber is used along with crude latex. This is the average of a period of 14 years. In some products reclaim improves the final output, which accounts for the fact that reclaim has sold for higher prices than natural rubber. The recent national campaign for scrap rubber was no sudden turn to untried practices. It was an effort to stimulate practices long established.

Sources of information for this brief history of natural rubber were the United States Department of Commerce, the Rubber Manufacturers Association and publications of Firestone Tire and Rubber Company, General Tire Company, the B. F. Goodrich Company, Goodyear Tire and Rubber Company and the United States Rubber Company.



Cured and baled, ready for shipment from a plantation processing plant.

Worthy Praise from a Worthy Source

"IT IS FORTUNATE that the program for the needed plants is generally in the hands of as competent engineers as there are in the country. Probably the most interesting and satisfying part of our study is the confidence we have acquired in the men from industry who have the plans in hand and who are satisfied they can lick the problem in the given time. Their competence and experience, their resourcefulness and ingenuity are the best guarantees we have that they can do so. We have been much impressed with the fact that this stupendous undertaking is only possible because of the highly developed skill of our technologists. No one could have examined the facts before us without appreciating the magnitude and scope of the task; no one could have made this study without realizing that because of the shortsightedness and failure to act on technically sound advice we must now proceed with insufficient experience. On this basis we venture the statement that never on the basis of so little has so much been involved."

—*From the Baruch Committee Report.*

Rubber Administrator to Follow Committee Recommendations

FOR CARRYING out recommendation of the Brauch committee in regard to synthetic rubber, William M. Jeffers, president of Union Pacific Railroad, has been named administrator. His selection by Donald Nelson, chairman of the War Production Board, gave all authority of the chairman over the rubber program in all its phases.

Full control was further vested in the position by President Roosevelt, who informed all other governmental agencies of the change. The effect is to give all responsibility of the rubber program to the War Production Board.

In regard to providing ingredients for synthetic rubber the administrator will carry through these recommendations of the committee: no further substitution in plans; authorization of an addition 140,000 tons of Buna S capacity per year; immediate institution of a refinery-conversion program to yield 100,000 tons of butadiene in addition to that now planned; adjustment of rates of construction of styrene and polymerization plants to assure maximum production of Buna S rubber in 1943; additional capacity for 20,000 tons of noeprene per year; erection of a butadiene plant of 27,000 tons capacity from grain with an associated polymerization plant for 30,000 tons of Buna S rubber; immediate erection of alcohol plants to produce 100,000,000 gallons per year.

The full report of the committee of which Bernard M. Baruch was chairman, James B. Conant, president of Harvard University, and Karl T. Compton, president of Massachusetts Institute of Technology, other members, dealt with all phases of rubber and recommended gasoline rationing on a national basis as one means of rubber conservation.

The complete report follows:

1. Statement of the Problem

Of all critical and strategic materials, rubber is the one which presents the greatest threat to the safety of our nation and the success of the Allied cause. Production of steel, copper, aluminum, alloys or aviation gasoline may be inadequate to prosecute the war as rapidly and effectively as we could wish, but at the worst we still are assured of sufficient supplies of these items to operate our armed forces on a very powerful scale. But if we fail to secure quickly a large new rubber supply our war effort and our domestic economy both will collapse. Thus the rubber situation gives rise to our most critical problem.

Our position with respect to this vital commodity may be briefly outlined as follows:

The demands now placed upon us are enormous. Without any allowance whatsoever for civilian passenger car tires, the estimated requirements for the year 1943 are 574,000 tons. This contrasts with the total average over-all consumption in the United States before the war of over 600,000 tons. We must supply not only the needs of our own armed forces but much of those of the military machines of our Allies as well. We must equip our buses and trucks and other commercial vehicles and provide on a large scale specialty items for such purposes as factory belting, surgical, hospital and health supplies. And in addition to all these we must maintain the tires on at least a substantial portion of our 27,000,000 civilian passenger automobiles. Otherwise an economy geared to rubber-borne motor transport to an extent not approached elsewhere in the world will break down.

To meet these demands we may look to four main sources of supply:

First, our present stockpile of natural rubber and such additions as may come to it from natural-rubber imports from Latin America, Africa, and other rubber-producing lands. These are comparatively small.

Second, our present stockpile of scrap rubber, estimated as sufficiently large with yearly additions to operate our reclaiming industry at present capacity through the year 1945.

Third, the production of synthetic rubbers.

Fourth, we possess in the tires of our automobiles a priceless reserve, which must be guarded with greatest care. It represents a stockpile of some 1,000,000 tons of rubber applicable to the uses of our civilian transportation and the needs of the day-to-day life of our people.

Having lost to Japan 90 percent of our prewar source of natural rubber, chief reliance on new supplies of rubber must be placed on the new synthetic-rubber program. But to obtain this in time we must, within two years after Pearl Harbor, have created one of the largest industries in the country. Normally such a development would require a dozen years. To compress it into less than two years is an almost superhuman task.

Our committee is convinced that the government's present program is technically sound. From this time on the important thing is to get on with it without further delay.

In drawing up the recommendations which follow the committee has sought to find a basis upon which the entire nation can go forward together, uniting our energies against the enemy instead of dissipating them in domestic wrangling. It appreciates that it is asking the public to make sacrifices because of mistakes that have been made and for which the people are not to blame. But wrong things done in the past cannot be cited as a defense for making mistakes in the future. The war demands that we go forward from this point united and resolved to win at any cost.

2. Procedure of the Committee

This committee was asked "to get the facts and make recommendations." To this end, immediately after its appointment it assembled a competent technical staff of approximately 25 men of whose competence we had knowledge through first-hand experience. With the aid of this group the committee has endeavored as far as humanly possible in the time at our disposal to get the facts and draw from these facts the logical conclusions.

With the aid of experts in the art of rubber manufacture and rubber compounding and with the assistance of a group of chemists and chemical engineers, we checked so far as possible the chemical processes involved in the government program and those suggested by individuals and companies not yet included in this program. For this purpose members of our staff traveled throughout the eastern, southern, and middle western sections of the country, examining plants, consulting the technical experts concerned with the progress of the program and in the construction of new facilities. With their aid, we also examined carefully the present status of all tests throwing light on the adequacy of the new synthetic materials for military and civilian purposes, as well as the potentialities of numerous materials which have been suggested for the recapping of tires or special uses in the rubber program. We also examined at first hand into the condition and state of protection of the nation's stockpile, which must serve as the essential backlog of our efforts until synthetic materials can be brought into substantial production.

Special checks likewise were made by men competent in business and engineering associated with the committee, as to the rate of construction of scheduled plants and the situation with respect to the allocation of strategic materials to these plants and the granting of the necessary priorities. The capacity of the country to produce the essential raw materials for the development of the synthetic program also was checked. We have endeavored with the

View showing spring compensated cross head guiding valve stem and connection with valve stem. Thrust adjustment mechanism and thrust indicator.

THE NEW S. C. LIMITORQUE VALVE CONTROL

. . . can be used on gate, globe or angle valves from 3″ to 24″ diameter.

. . . keeps maintenance far lower than ever heard of heretofore. The lack of need for the conventional threaded valve stem and mating nut is but one reason for these savings.

. . . being a crank mechanism, operates with a rate of speed that is not uniform. On closing, speed is accelerated until valve is about 50% closed then decelerates so that upon seating, the rubbing velocity of the valve seating surfaces is minimized and shock to any part of the valve avoided.

. . . avoids application of impact loads to disc and seating surfaces of valve. Setting for light or heavy seating is easily achieved simply by adjusting one stud. Thrust is uniform on all springs. Once set the seating remains the same until a change is desired.

. . . prevents jamming of gates in seats of valves.

. . . is smooth and quiet in operation.

. . . requires only one switch, saving in wiring installation time and upkeep. This is a 12 pole drum switch that operates opening and closing limits and indicating lights and allows a balance of 8 poles that may be used to actuate interlocking relays and alarms or to directly interlock valves. Switch is accurately timed and set at the factory so no field adjustments are required.

. . . has a cross head equipped with compensating springs to assure tight seating regardless of temperature variations. The connecting rod driving the cross head stops on dead center, so that once closed the valve cannot "back-up."

. . . is provided with a handwheel for manual operation that drives through differential gearing so motor is always engaged. Control is constantly operative, either electrically or manually. Handwheel does not rotate when in motor operation and Motor does not revolve when in manual operation.

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RAILROAD MAN BECOMES RUBBER CZAR

WILLIAM M. JEFFERS

President of the Union Pacific Railroad, appointed National Rubber Administrator by Donald M. Nelson, War Production Board Chief, in line with recommendations of the Baruch Committee that the rubber problem be placed in the hands of a single agency.

aid of competent assistance to evaluate the potential requirements of this country and the United Nations and have made our estimates of the probable supply, present or to come.

In addition to interviewing, through our staff, a number of persons familiar with the various aspects of the rubber situation, we heard formally many officials of the government as well as representatives of industry. A great number of documents from governmental and other sources were put at our disposal, and we examined these records with care. The printed records of hearings before the committees of Congress which deal with this subject run to many pages. We reviewed the evidence thus presented as of value on many points. All of the Congressional committees who had interested themselves in the problem were asked for their suggestions or recommendations and many stimulating suggestions were made. Particularly helpful were the committees under the chairmanships of Senators Truman, Gillette and Murray. In conclusion, it is a pleasure to acknowledge that from all with whom we have been in touch we have received the maximum of cooperation.

3. Analysis of the Supply and Demand for Rubber

The natural starting point for a consideration of our national rubber problem is an estimate of the essential needs during each of the next few critical years, and a corresponding estimate of the sources of supply from which these needs may be met. Many such balance sheets of the national position have been drawn up by various governmental agencies during the past eight months, and authoritative revisions must be made from time to time to give warning if our program is running behind expectations, or to give opportunity to make additional important military uses of rubber if the program should run ahead or schedule, or to relax restrictions on civilian driving.

In arriving at the data presented in the accompanying tables, which form the principal bases of the committee's conclusion, we have tried to be neither unduly optimistic nor unnecessarily pessimistic. The figures in each case represent our best judgment of expected performance. We realize, and this should be continually borne in mind, that unanticipated events may change many of these figures substantially. We should also bear in mind that there are many more circumstances which might arise to change the figures unfavorably than there are to change them favorably. Such circumstances are likely to arise from human rather than technical reasons, and some of these circumstances will constitute the basis of recommendations in Section 7 and 8.

Considering first the anticipated supplies of all types from all available sources, our estimates are presented in Table 1. In this table have been included certain additions of neoprene and Thiokol to the present governmental program, in accordance with recommendations presented in Section 6. However, the recommendations there given for increasing the supply of Buna S rubber as a safeguard for the critical year of 1943 and a backlog to maintain civilian transportation after 1944 are not included in this table.

This table does not include small amounts of Buna rubbers produced from private sources in 1942.

Against these supplies of natural and/or syntehtic rubbers, the presently estimated total requirements for various categories of essential use are presented in Table 2. In our calculation the use of synthetic rubbers has been stated in terms of equivalent tonnage of natural rubber by the use of factors depending upon the specific gravities and resistances to wear of the various types of rubbers, as appropriate to the specific uses included under each classification. The item "private transportation" does not include the reclaimed rubber or synthetic materials necessary to maintain private-passenger-car transportation, these being shown in Table 5. The item "private transportation" does, however, give the amount of natural rubber which would have to be used in addition to the reclaim and synthetic rubbers of Table 5 as a cement in recaps and new tires made of reclaim. The item "British deficiencies" shows the

TABLE 1

Supply

Before any consumption, the supply of rubber available to the United States, as estimated by the Committee's staff, is as follows (in thousands of long tons):

	Present Stocks July 1, 1942	Expected 1942 6 Months	Additions 1943	Additions 1944
Natural	578	12	41	68
Buna S	...	0	386	705
Neoprene	...	4	30	59
Butyl	...	0	62	132
Thiokol	...	0	54	60
Reclaim	47	160	360	400

B&W ALLOY TUBE SUPPORTS

More than two million pounds of Babcock & Wilcox Tube Support Castings in high-temperature furnaces have been supplied, and not a single service failure has been reported. Service temperatures range as high as 2000 F. under conditions requiring high creep strength, consistent with long-time stability. The castings include all types of supports, together with related links, bolts, nuts, etc.

B&W INTEGRAL FURNACE BOILERS

This type of boiler, a thoroughly coordinated unit of modern design, possesses advantages of especial value in refinery installations. Installation requires minimum alteration of existing structures. A wide variety of fuels is permissible. Particularly notable for their simple, practical construction which makes them exceptionally easy to operate and maintain. *

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S-30 T

expected requirements of the British Empire excluding Canada as its accumulated stockpile of natural rubber is consumed.

TABLE 2

The total requirements of natural and/or synthetic rubbers (in terms of natural) are estimated as followw (in thousands of long tons):

	1942 6 Mos.	1943	1944
Military	138	325	325
Private transportation	1	3	3
Commercial vehicles	28	59	85
Other civil uses	24	49	50
Foreign countries	74	117	103
British deficiency	0	24	106
	265	577	672

The item "commercial vehicles" in Table 2 refers primarily to passenger buses and trucks whose operations are controlled by the Office of Defense Transportation with cooperation of the Office of Price Administration in matters of rationing. Under the ODT steps have been taken to conserve rubber through consolidation and rerouting of commercial traffic, and as this is written, by an order requiring a certificate of necessity and imposing gasoline rationing. Our committee believes that further savings can be made through elimination of cross hauls and more stringent substitution of alternative types of transportation not requiring rubber. Our estimates in Table 2 for commercial vehicles depend upon limitation of speed, conservation of tire wear and maximum proper loading.

The item "other civilian uses" includes several hundred items such as rubber hose, belting, electrical insulation, storage battery separators, industrial footwear, medical equipment, etc. The committee has carefully examined the program of the Rubber Branch of WPB with reference to the elimination of unnecessary use of rubber in such items or the substitution of lower grades of rubber and is convinced that a thoroughly competent job has been done in reducing the use of rubber in such items to a point at which very little further reduction can be expected in this list. A few remaining possibilities are being actively studied by the Rubber Branch, but the sum total of all such possibilities is estimated to be so small that the time when the nation might run out of crude rubber could not be postponed more than ten days if all such reductions, some involving considerable hardship, were enforced.

An essential part of our rubber supply is in the form of reclaimed rubber secured from the stockpile of scrap rubber. To the estimated 47,000-ton stock of reclaimed rubber on July 1, 1942, is added year by year the additional amounts of such rubber which it is estimated can be produced by the capacity of our rubber reclaiming plants. These plants are not now running to capacity because of the governmentally enforced limitations in allocation of reclaimed rubber to manufacturers. The demands listed in Table 3 are based on the assumption that all possible excess of reclaimed rubber be allocated to maintenance of civilian passenger-car tires. In order to secure these amounts for private transportation, and to insure adequate provision for military and other needs, the committee recommends in Section 10 that plant capacity for producing reclaimed rubber be expanded as rapidly as possible above its present limit of 350,000 tons per year, and the effect of such expansion is reflected in the estimates of "supply."

TABLE 3

Supply and requirements of reclaim are estimated as follows (in thousands of long tons):

	1942 6 Mos.	1943	1944
Supply	207	360	400
Requirements:			
Military	37	84	84
Commercial vehicles	18	33	43
Other civil uses	72	146	146
Foreign countries	18	21	21
Balance Available for Passenger Cars	62	76	106

If in the requirements in Table 2 we substitute the various types of synthetic rubber to the extent that they are expected to be available and for the purpose for which they are suitable, we can, from Tables 1 and 2, deduce the amounts of crude natural rubber which we will have on hand at various times, as indicated in Table 4. In deriving this table we have reserved for civilian passengar-car tire use all of the Thiokol of Table 1 (since this material is not suitable for many other uses), and we have also reserved a small amount of butyl rubber and a considerable amount of Buna S rubber in 1944 for similar purposes, as shown in Table 5. With these reservations the amounts of natural rubber available in the United States are shown in Table 4.

The amount remaining for application to civilian passenger transportation is estimated to be as shown in Table 5.

Two comments on the tables are important. The first is that the amount of rubber available for civilian passenger car tires is a relatively small residual left over from a very large program, and must absorb the shock of any miscarriage of our plans. The committee has assured itself that a strong effort has been made to hold the military, allied, and other civilian requirements to a minimum. Since the amount left over for civilian passenger tires is a small residue, any unfavorable change in the above figures would tend to squeeze out the amounts left for civilian driving. This is the strongest argument for a drastic program for conservation of the existing tires on civilian passenger cars, since any failure to conserve these tires, combined with either an increase in military requirements or a delay in securing the expected production of synthetic materials, would result in a complete breakdown of civilian passenger-car transportation in 1944 or 1945.

The other important comment is that the balances shown for crude rubber in Table 4 are very little above the requirements of prudence. This can be illustrated by examining the balance of 224,000 tons expected to be left at the end of 1943. This balance includes the inventories necessary to manufacturers of rubber goods in order that they may continue manufacturing operations without delays caused by temporary transportation or procurement difficulties. Of this 224,000 tons, about 50,000 tons would represent a 30-day inventory for American manufacturers, which is none too large. Another 4,000 tons can be considered as a reasonable inventory for Canadian manufacturers.

TABLE 4

Estimated crude natural rubber in the United States, after application of synthetic rubber substitutes (in thousands of long tons):

	1942 6 Mos.	1943	1944
Balance on hand	578	328	224
Added during period	12	41	68
Requirements	262	145	51
Annual excess	....	....	17
Deficiency	250	104	....
Balance carried over	328	224	241

The committee believes that at least 66,000 tons should be considered as an inventory of stocks on hand in Great Britain to permit her rubber goods manufacturing to proceed in case there should be several months' interruption of transportation on account of a possible change in the naval situation in the Atlantic Ocean. Thus about 120,000 tons out of the 224,000-ton balance is to be considered a necessary "working inventory." The balance of 100,000 tons is certainly none too large for safety when one considers that a delay of two months in the presently expected production schedule for Buna S rubber would completely wipe out this balance. In this connection it must be remembered that a substantial amount of crude rubber must always be in hand to blend with synthetic materials for various important uses.

For these reasons the committee feels that an analysis of the balance sheet indicates: (1) that we can survive the rubber crisis without serious impairment of our military program or domestic economy if the plans go through on schedule, but that (2) the margin of safety is uncomfortably small in view of reasonably possible unfortunate contingencies. The committee therefore recommends in Section 6 certain expansion of the present program to aid the civilian driving program and as an insurance against such contingencies.

The committee also recommends that WPB through the Rubber Administrator scrutinize all requirements, foreign and, domestic, submitted for rubber to the end that only actual needs be allowed for.

4. Rubber Requirements of the Armed Services

The rubber requirements of the armed services have been stated in terms of over-all tonnage in Table 2 of Section 3. It would not be appropriate in this report to discuss the individual items which make up these requirements. Suffice it to say that our committee has examined these requirements in some detail and submits the following comments.

It is reassuring to note that the Army has cut its requirements by about 45 percent; the Navy, by about 35 percent with expectation of raising this to 45

TABLE 5

Rubber applicable to civilian transportation is estimated as follows (in thousands of long tons):

	1942 6 Mos.	1943	1944
Crude natural	1	3	3
Buna S	0	0	185
Butyl	0	0	15
Thiokol	0	54	60
Reclaim	62	76	106

FUEL AND ENGINE RESEARCH IS NOT "AS USUAL"

AT THE TIME when the new Ethyl laboratories were planned, the clouds of war were but a tiny speck on the horizon—too small to be noticed by the great majority of Americans. But as construction proceeded it became more and more apparent to its builders that the 26-acre plant at Eight Mile Road, Detroit, might soon have to devote some of its facilities to problems of military fuels and engines.

Then came Pearl Harbor.

Immediately all plans for research to improve civilian vehicles and fuels were shelved and all the facilities of the then nearly completed plant were offered to the Government. Today, in cooperation with the technologists of the automotive, aviation and petroleum industries, Ethyl engineers are working to help give American motorized equipment the extra power, efficiency and dependability that are all-important in modern warfare.

We believe that winning the war is the prime job of every American. But, because we have an unbounding faith in the ability of our country to crush aggression, we are trustfully looking forward to the days when the grim lessons of war can be translated into progress in peacetime transportation.

★ ★ ★

ETHYL CORPORATION
Chrysler Building, New York City

★ ★ ★ *Manufacturer of antiknock fluids used by oil companies to improve gasolines* ★ ★ ★

percent. These differences are largely on account of the differing types of requirements in these services, and the committee believes that both services have handled their rubber-conservation program sincerely and effectively. The committee accepts at full value the statement that substantial further reductions cannot be made without a serious reduction in military efficiency. It also recognizes that large combat losses might, on the other hand, substantially increase the rubber requirements of the armed services above their present estimates.

The following comments amplify the general statement just made and are based upon the committee's examination of the estimates and performances of these services. In general, the estimates are based upon:

(1) a recognition of the dangers inherent in the short supply of rubber;
(2) a sound method of calculation of needs on the present facts as to the size of the armed services. (The committee does not attempt to measure the need for the items using rubber, but only the need for rubber is estimated if the items are purchased).
(3) the establishment of an organization to develop and push the conservation program, with competent personnel, keeping in touch with all developments in the conservation of rubber;
(4) a quite complete policy as to the elimination of rubber articles formerly in use in the service and providing for substitutes generally where possible;
(5) a careful examination of all specifications covering rubber goods so as to reduce the crude-rubber content, and increase the use of reclaimed rubber or substitutes;
(6) tests for utilization of rayon, nylon and steel (in place of cotton) which, being stronger, will demand less rubber;
(7) a comprehensive plan for conserving rubber in use and suitable orders and instructions covering its operation.

While there is no adequate measure as to the actual accomplishments in the field, the reports from inspection are encouraging in some spots and discouraging in others, but the organization set-up appears sound. In one area of extensive army training maneuvers where previous inspections had disclosed very wasteful practices in the use and abuse of tires, a recent inspection by the same experienced civilian group led to their report that the tires in this area were now being conserved with at least as good care as would be found in an operating fleet of commercial vehicles. This part—the making of the plan effective in the field—will require a vigorous follow-up, training of operating and inspecting personnel, aided by rigid inspections, and adequate disciplinary measures.

All these things can be done readily without interfering with military effectiveness. Three other aspects of conservation of rubber are under study by the services and some progress has already been made, but there is need for careful work and prompt decision as to whether:

(a) the conditions under which equipment will be used permit redesign of the equipment so as to save rubber, for example, the use of steel wheels or rims instead of rubber tires to a greater extent;
(b) the experience in combat does not warrant the use of equipment using either lower grade or less rubber, so that the rubber will not be planned to outlast the remainder of the equipment;
(c) requirements for spares cannot be materially reduced;
(d) inner-tube requirements cannot be cut as tubes out-last tires;
(e) depreciation is not less than estimated, due to the conservation plans.

The full utilization of existing inventories through complete inventory control, the avoidance of purchases whenever possible, the scrutiny of all unusable items—both new and scrap—in inventory and providing for their prompt utilization in the armed services, or elsewhere in the war effort are matters now in hand but still demanding rigorous prosecution.

The armed services assure us that this entire program will be carried out to the limit.

The savings expected are not large and if attained they are enough only to provide a small factor of safety required for the whole national program.

5. Tires for Passenger Automobiles

The adoption of a policy for conservation of civilian-owned tires and its enforcement at the earliest possible moment is unquestionably the most urgent item still remaining unsettled in the rubber program. The cost to our war effort of not doing this would far exceed the cost in materials and rubber of doing it.

It must be remembered that practically nothing has been done during this year to supply tires for the 27 million passenger cars now on the road. In normal years about 250,000 tons of crude rubber has been consumed annually in meeting this demand. Many tires are now reaching the point where they will become unusable, and unless something is done at once to provide recaps and a limited supply of new tires we shall be headed for a drastic breakdown in the not far distant future. It has been estimated that by April of 1943, one half of the tires on passenger automobiles will be worn to the point where they should be recapped. Clearly if such a condition is reached it would not be many months before our civilian economy collapsed.

In the committee's opinion it is unfortunate that the government was not able to institute a tire replacing and recapping program last spring. If it could have been done many billions of car miles of rubber would have been conserved. It is of the utmost importance that this program be instituted at once together with provisions for adequate tire inspection. Experience has shown that out of every 100 tires ready for recapping only about 60 can be thus repaired. The other 40 tires must be replaced by new tires. It is primarily this fact which sets the limits to any program which can now be instituted for conserving our rubber-borne transportation through a recapping program. If we were to decide tomorrow to provide enough new tires and recaps on the prewar basis of replacements to carry the 27 million passenger cars through 1943, with unrestricted driving as to speed and mileage on the prewar level, some combination of crude and reclaimed, as for example about 200,000 tons of each, would be required. Clearly the allocation of such amount of crude rubber or synthetic material for the use of civilian passenger cars is fantastic. The committee must emphasize once again that the critical time for the country, as far as rubber for its military effort is concerned, is the third quarter of 1943 and the quarters immediately succeeding. This is evident since many of the plants now under construction for the production of synthetic rubber will not reach full operation until the latter part of the coming year. Our analysis shows that even with the optimistic estimates of the total quantities of new crude and synthetic rubber that will be available the amounts of this that we will be able to spare for the purpose of civilian passenger cars will be sufficient for a recapping and tire-replacement program only provided that strict conservation measures are instituted at once.

The committee is well aware of the fact that the American people are quite prepared to make any sacrifice that is needed for the winning of this war. No one will complain of hardships or discomfort when he thinks of the young men who are now preparing to give their lives freely on distant battlefronts throughout the world, but the committee does not believe in the doctrine of sacrifice for sacrifice's sake. Neither do we believe that civilian workers should be expected to live in tents and walk several miles to work unless it can be demonstrated beyond the shadow of a doubt that the situation is so desperate that there is no alternative except that of inviting military defeat. Consequently the committee has explored carefully the amount of rubber which can be spared for the purpose of keeping the passenger cars of the country in operation. We realize full well that beyond some point we cannot limit the amount of transportation thus carried throughout the country without severe effects to our war program. Indeed we have been given estimates that point to the fact that unless approximately 50 percent of our normal annual car mileage can be maintained our normal productive effort would be seriously retarded. Necessary civilian needs are a part of the war effort. Ludendorff complained that the home front crumbled before the war front. We must provide for the bottleneck of lessened automobile transportation before it occurs.

If we could be absolutely certain that all the production of synthetic rubber planned for 1943 would come in on time and that no difficulties would be had in the initial stages of using this material, it might be safe to draw on the existing stocks for the rubber with which to manufacture tires for passenger cars. It is essential, however, that we have a margin of safety for our military effort, and no civilian in this country would ask the government to jeopardize our war machine through lack of rubber in order that he might drive a few miles further in his car.

The average annual mileage of the passenger automobiles before the war has been estimated as approximately 9,000 miles. Today the figure usually quoted is 6,700 miles. It is clear that in the non-rationed areas the diminution in annual mileage is a result of voluntary restriction brought about largely by the fear that no further tires will be forthcoming for the owner of a private car. There is every reason to believe that as soon as a tire re-

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These processes are importantly increasing production of two war materials that are most critically needed today, *synthetic rubber* and *high octane gasoline*. Refiners, natural gasoline manufacturers and others who have raw materials from which these products can be made are urged to obtain complete information immediately, both in the interest of the war effort and in the interest of their own progressive development during and after the war.

Of vital importance to those who can use these commercially proven processes is the fact that Phillips research scientists are constantly studying these processes, constantly checking different combinations of charge stocks, catalysts and operating procedures in search of means to increase the production of these processes and to increase their contribution to the war effort in other ways. Thousands of laboratory and pilot plant tests have been completed, and on the basis of this tremendous background of experience, tests are continuing along the lines that show the greatest possibilities.

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placement and recapping program were announced without restrictions, drivers would feel that the danger had been passed and would increase both their speed and their mileage to almost pre-war levels. If this were done the amount of rubber consumed by any recapping and tire replacement program would reach figures so large as to go beyond our expectations of supply in the critical year 1943—250,000-300,000 tons of Buna S, almost the entire production if the least optimistic estimate proves to be correct.

Strict enforcement of a speed limit of 35 miles per hour for private automobiles together with adequate tire inspection are extremely important factors in conserving rubber. The committee recommends that these measures be instituted at once on a nationwide scale. On this basis it would be possible to provide enough new tires and recap to maintain the program here recommended, if a maximum of 138,000 tons of reclaimed rubber were made available during the next 16 months for the purpose of keeping the passenger cars of the country in operation. (The small amount of crude rubber which is required in connection with the recapping program amounts to only a few thousand tons). This amount of rubber, supplemented by synthetic materials as shown in Section 6, we believe will enable the nation to maintain approximately the present number of passenger automobiles at an average annual mileage of 5,000 miles.

In order to insure that this mileage will in fact prevail the committee recommends that nationwide gasoline rationing be instituted at the earliest possible moment under policies to be determined by the Office of Defense Transportation and implemented by the Office of Price Administration. The committee has examined various alternatives to gasoline rationing as a means of conserving rubber, but by no other procedure can we be certain that the annual mileage will be held to the figure we name. We must have some assurance so that those individuals who are ready to lead in the conservation of rubber will not be taken advantage of by the small percentage of the population who are not ready to follow.

It must be clear that this program would not give every citizen the right to drive 5,000 miles. This figure is an average which obviously means that the mileage for unnecessary driving must be cut very considerably below this figure, in order that essential driving requiring greater mileage may be maintained. The proper distribution of mileage to various drivers is a matter which would be worked out by the responsible governmental agencies.

It should also be stated that, in the committee's judgment, even the above drastic curtailment of driving will be insufficient to meet the situation unless there is further increase in the practice of car pooling and sharing of rides. Extra tires of popular sizes now in the possession of persons who will not need them could be made available for essential uses under a suitable program of pooling through voluntary sale to the government.

Every day of delay in putting the above program into effect will mean irretrievable, unnecessary loss of rubber by America, and will build up, if long delayed, a day of disastrous reckoning. The nation is now driving on rubber borrowed from a happier past. Without recaps and replacements the majority of civilian cars would be forced off the road by irreplaceable tire failures.

If by the end of 1943, actual production is realized from the synthetic rubber plants under construction to the extent that is now scheduled, and if the synthetic rubber can be used as readily as it is believed, or if the military and export demand for rubber should actually prove to be substantially less than is now anticipated, it would be possible to draw further upon the stocks of rubber before 1944 for civilian passenger-car use. In that case, the restrictions on driving could be lessened, provided that the Rubber Administrator feels sure that by 1944 at least 100,000 tons of Buna S will be available for tires for civilian driving. In order to make certain that this will be the case, the committee is recommending elsewhere such an expansion of the present synthetic program as to provide for this excess synthetic rubber. This, we believe, can be done without interfering with the war program. The drastic conservation measures recommended for the year 1943 may therefore be somewhat relaxed after another 12 months has passed, if the situation in regard to synthetic rubber is as rosy as we may hope.

At this point the committee wishes to correct the erroneous impression which has been spread abroad to the effect that tires on cars standing in the garage will deteriorate almost as rapidly as if they were being driven. This idea is completely wrong. When standing under proper conditions in a garage the deterioration of the tires amounts to only a very few percent, even in the course of an entire year. The conditions which must be observed are that the tires must not be allowed to stand uninflated, that they should not be allowed to stand on oil or grease, and that the car should be jacked up to relieve the pressure on the tires if the car is to stand for several months without use. High temperature and sunlight also have a deleterious effect. With any reasonable observance of these precautions, cars may be kept in storage with almost complete saving of the remaining mileage in the tires.

In the interim the committee is confident that the American people, once they are acquainted with the true facts in regard to our rubber supply, will gladly accept whatever conservation measures are required.

To sum up, our recommendations, in so far as passenger automobiles are concerned, are as follows:

1. Immediate institution of a tire replacement and recapping program through the allocation of reclaimed rubber for that purpose.

2. Nationwide gasoline rationing to hold the average annual mileage to 5,000 miles under the general direction of the Office of Defense Transportation.

3. Prompt and strict enforcement of a nationwide speed limit not exceeding 35 miles an hour for private passenger cars and trucks.

4. Compulsory periodic tire inspection.

5. A voluntary interim tire conservation program until gasoline rationing can be instituted.

In order to provide for the recapping program which we have previously outlined it will be necessary to expand immediately the facilities for the production of Thiokol. At present the country has plants for the production of 24,000 tons per year from private sources; this should be enlarged by government-sponsored plants to produce 36,000 tons by conversion of present existing idle plant capacity, giving a final total of 60,000 tons per year. Thiokol is most rapidly produced of all of the synthetic materials which are suitable for the retreading of civilian tires. The amount indicated will be needed to help carry civilian passenger tires through the years 1943 and 1944. If prompt action is taken the additional Thiokol should be in production by January, 1943.

Adequate tire inspection is one important element in the conservation program. In general, where industry can be organized to function, great care should be taken not to build a duplicate governmental organization. This has special reference to periodical examination of civilian tires. It would seem very much easier to license recognized tire dealers and repair men who have experienced help and who are fully equipped for the purpose of examining tires and advising as to their maintenance. Such an organization could be created almost over-night. Rationing boards would then be governed by the reports presented to them by those requiring tire recapping or repairs from the information furnished by these examiners. The committee suggests that these examinations be governed by a mileage total instead of elapsed time.

6. The Synthetic Program

The present plans for the production of synthetic rubber as outlined to us by the governmental agencies concerned call for the erection of the following types of plants in the United States:

(a) for the production of neoprene, eventual capacity 40,000 tons per year (in addition to a 9,000-ton plant now in operation by a private company);
(b) for the production of butyl rubber to yield 132,000 tons per year;
(c) for an over-all production of 705,000 tons of Buna S.

This production of Buna S involves construction in terms of plants for producing styrene and butadiene and for the copolymerization of butadiene and styrene with the formation of Buna S.

For the manufacture of butadiene the following processes are scheduled: (all figures expressed in the long-ton equivalent of Buna S):

(1) from alcohol by the Carbide and Carbon Chemical process, rated capacity, 242,000 tons;
(2) from butane (in natural gas) by a process developed by Phillips Petroleum Company, 50,000 tons;
(3) from butane by the Houdry process, 16,500 tons;
(4) from butylene (obtained by the cracking of petroleum) by a process developed by Standard Oil Company (New Jersey), 283,000 tons;
(5) by the cracking at high temperatures of gas and heavy oils (the so-called thermal or refinery-conversion processes), 20,000 tons;
(6) by combination of (4) and (5) in one locality, 93,500 tons.

The committee has examined the present status of the government's schedules and estimates that if the construction program can be met on the dates specified there will be pro-

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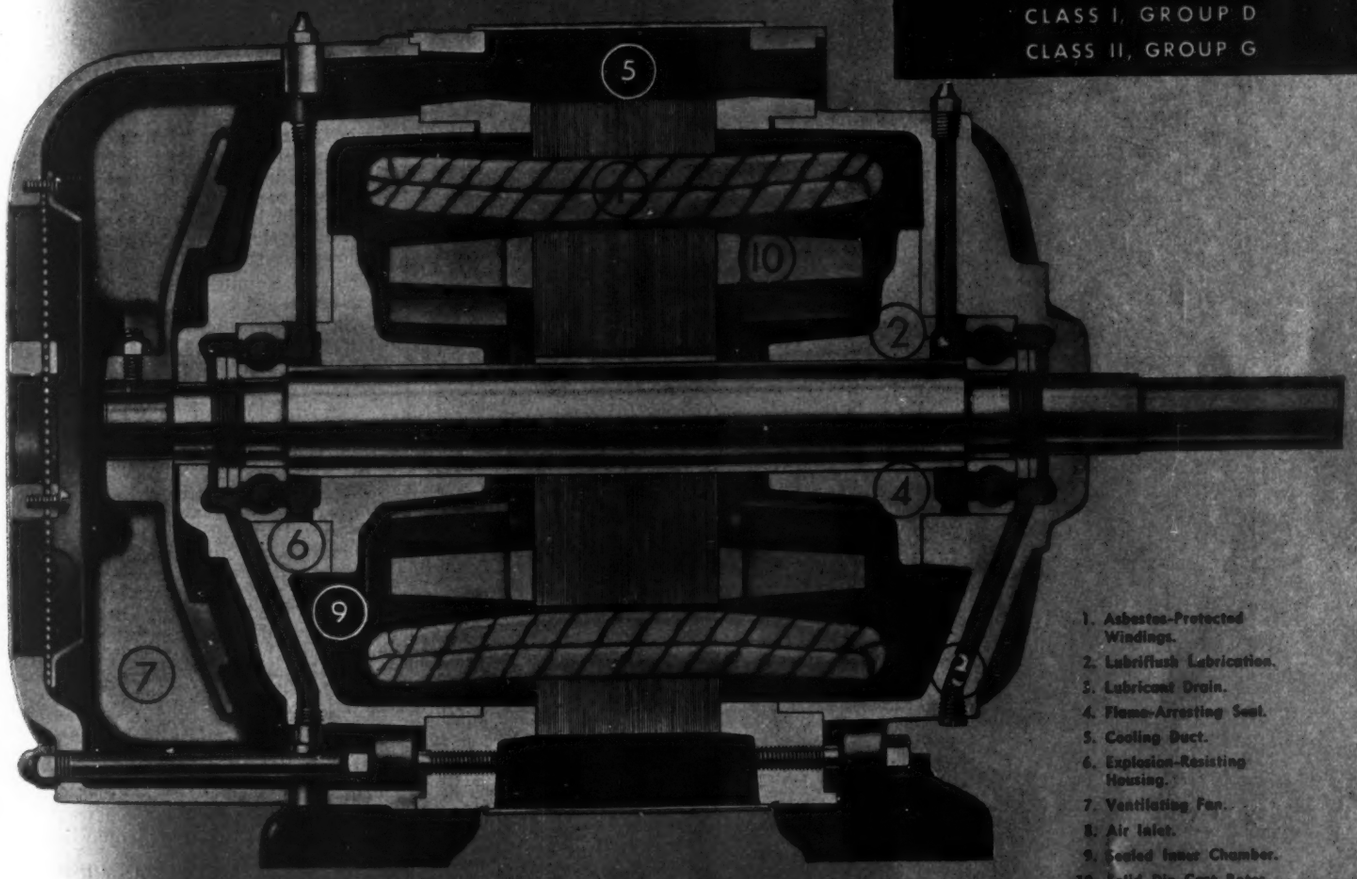

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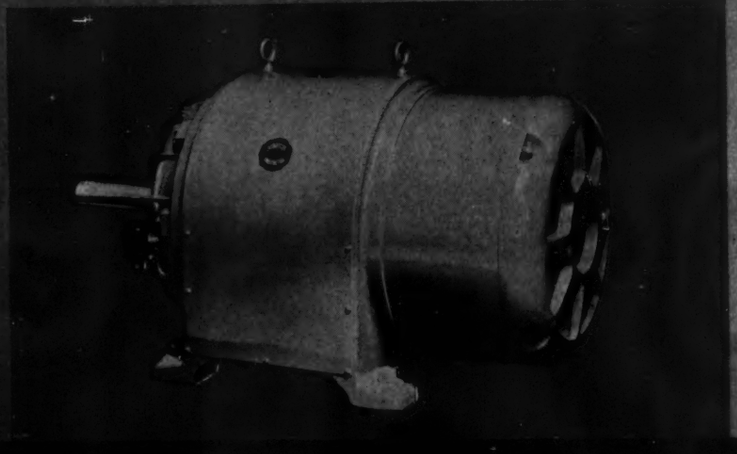

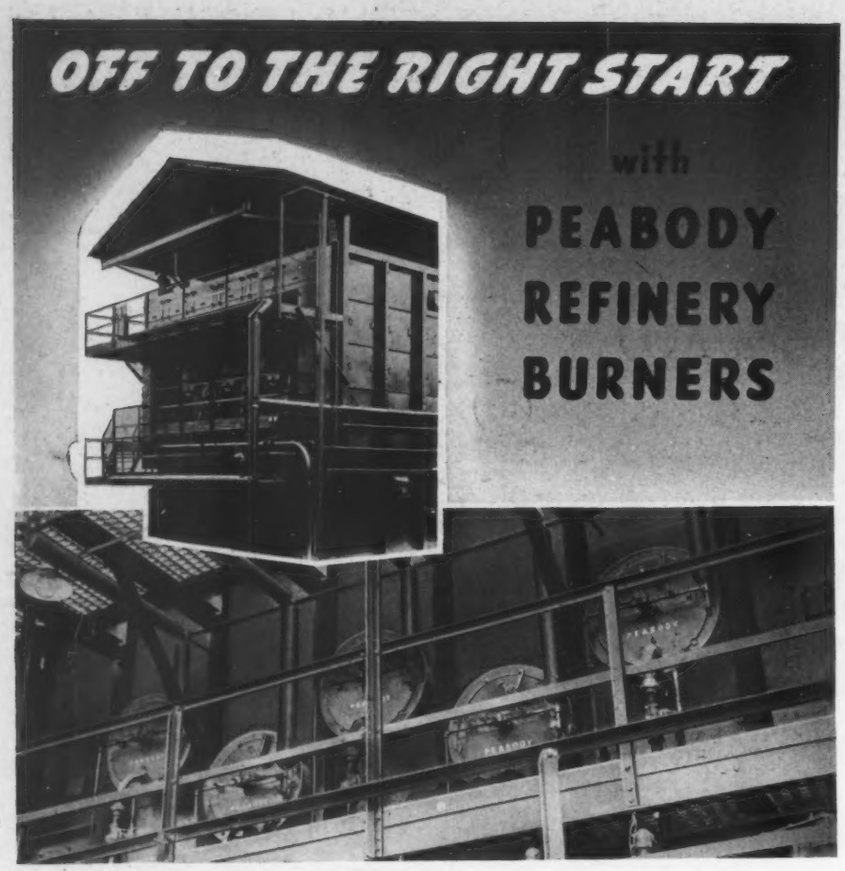

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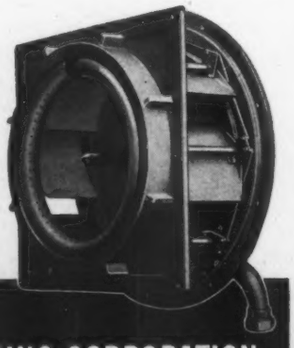

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duced during 1943: 400,000 tons of Buna S; 30,000 tons of neoprene (in part from private sources). We believe that these processes will ultimately work on a large scale and yield satisfactory products.

Furthermore, our experts estimate that the time required to get the various plants running smoothly under actual operating conditions will not be so lengthy as to cause serious delay. On the other hand it must be remembered that we are dealing here with a new industry and that in the production of Buna S three separate manufacturing operations are concerned, no one of which has been carried out as yet on anything approaching the present contemplated scale.

Therefore, until more experience has been gained by the operation of one of the large-scale units at each step, we must consider that a considerable element of risk is present in the picture. The importance of completing rapidly one full-scale plant using each process and the erection of pilot plants is considered in the technical section of this report.

The committee wishes to emphasize once again at this point that the whole question of obtaining synthetic rubbers in adequate amounts in 1943 hinges on the rate of construction of the manufacturing plants. Unless the present situation involving the assigning of priorities and allocating of materials is improved, there is grave danger that there will be serious delays in the completion of the plants and consequent reduction in the amount of synthetic materials produced. Furthermore, unless the administrative changes recommended in a later section of this report are put into effect, conflicting governmental plans with respect to the oil industry may seriously jeopardize the production of butadiene.

We have also examined with the aid of our experts many other processes for the production of butadiene and synthetic rubber. We find that quite apart from their merits or demerits, no one of them could now be substituted in the present program with hope of accelerating the production of Buna S in the critical year 1943.

We would be blind if we did not see the efforts now in progress on the part of many companies to have a part in the development of a large new industry with vast postwar possibilities. This has been accentuated in the minds of the petroleum producers by gasoline rationing with its attendant loss of sales. They are thus forced to turn to other products including butadiene. Furthermore, we are not unaware that it is inevitable that once the war is over there will be a struggle amongst various groups for the control of this new industry. But all such considerations cannot affect this committee as to its conclusions. We are concerned only with the production of the largest amount of rubber in the minimum amount of time in order to carry the country successfully through the war. It is our firm conclusion that present processes for manufacturing synthetic rubber and the raw materials required (butadiene and styrene) must not at this late date be changed unless new processes can be shown beyond peradventure to have such advantages over those now employed that more rubber would be obtained in the ensuing months than would otherwise be the case. We have

found no such process in the course of our investigations.

The committee finds that there has been considerable discussion between two groups within the oil industry as to whether or not there was a serious conflict between the butadiene program based on butylene and the high-octane aviation gasoline program. With the aid of our experts we have examined carefully into this problem and consulted many technologists in various oil companies as well as discussing the matter with the officials of the Office of Petroleum Coordinator. It is our conclusion that, while the possibility of a conflict between the two programs does exist, it need not become serious if the possibility is recognized and if the administration of these two closely related enterprises is properly integrated.

The necessity for the administrative changes along these lines which are recommended elsewhere in this report is further demonstrated by the uncertainty of the stated aviation requirements both in quantity and quality. The evidence clearly indicates that if the present demands for high-octane aviation gasoline and butadiene stay where they now are, there need be no conflict.

If and when the armed services should decide that such larger quantities of high-octane aviation gasoline are needed, there are ways by which this demand can be met by the industry without diminishing the flow of butylene to the butadiene plants.

It is fortunate that the program for the needed plants is generally in the hands of as competent engineers as there are in the country. Probably the most interesting and satisfying part of our study is the confidence we have acquired in the men from industry who have the plans in hand and who are satisfied they can lick the problem in the given time. Their competence and experience, their resourcefulness and ingenuity are the best guarantees we have that they can do so. W have been much impressed with the fact that this stupendous undertaking is only possible because of the highly developed skill of our technologists. No one could have examined the facts before us without appreciating the magnitude and scope of the task; no one could have made this study without realizing that because of the shortsightedness and failure to act on technically sound advice we must now proceed with insufficient experience. On this basis we venture the statement that never on the basis of so little has so much been involved. Under these uncertainties the only recourse is to provide ample margins when in doubt.

The Problem of 1943

The year 1943 is so critical for the rubber situation that the production of 100,000 tons more or less of Buna S might be a determining factor in the success of our military program. In view of the extremely precarious situation in 1943 the committee recommends the prompt increase of 100,000 tons a year of butadiene over the present schedule, to be obtained by a refinery-conversion program. This can be accomplished with a very small expenditure of critical materials. This recommendation is designed to accomplish three ends: (1) fill the gap between butadiene production and polymerization capacity in the early part of 1943

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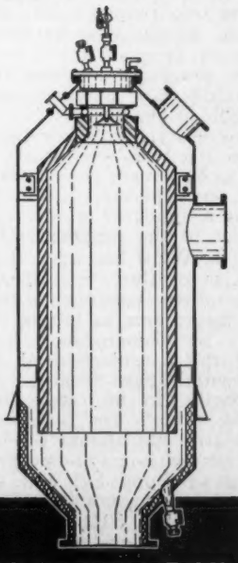

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(for the minimum polymerization capacity exceeds that for butadiene production and according to present schedule the two will not come together until the middle of 1943); (2) provide a reserve of stand-by capacity for the later years of the program; (3) furnish valuable insurance against contingencies affecting other plants in the program and provide additional facilities to meet possible increased demands of the armed services.

Due to the pressure from various sources there have been, even in very recent days, belated efforts to change from the present butadiene plants scheduled by the government to the refinery-conversion processes. The first thought that occurs to the committee is, "Why now? Why not months ago? Why the sudden activity? And, above all, why substitute at this late date?" We have recommended an increase, not a substitution, of a refinery-conversion program. We have made this recommendation, in order to produce more rubber during the critical year 1943. We should like to emphasize again that it would be a major blunder to make a further change inside the program at this date by the substitution of one process for another.

To obtain the maximum utilization of the combined refinery conversion program, we recommend a prompt increase in the rate of construction of polymerization facilities and of the styrene plants to balance the program upwards so that the maximum possible amount of Buna S might be produced in 1943. If this expectation and the optimistic estimates of the present schedule are realized, the Buna S produced in 1943 might be as much as 450,000 tons. Even this amount will not provide too large a margin of safety when it is recalled that our "carryover" to 1944, assuming only a 400,000-ton Buna S production, does not exceed 100,000 tons.

Looking Ahead to 1944

The present plans call for the building of polymerization plants with a rated annual output of 705,000 tons of Buna S. If the 100,000 short tons of butadiene (equivalent to 110,000 tons of Buna S) provided by the refinery-conversion program are to be utilized when the program is complete, additional facilities for polymerization must be provided and likewise for the manufacture of styrene. While there is evidence that the butadiene plants may produce 15 to 20 percent above their rated capacity, our experts have found no indication that a similar situation exists with respect to the polymerization plants.

The WPB has fixed the total annual output of Buna S at 705,000 tons. The committee recommends that this figure be raised now to 140,000 tons, and that this be accomplished by authorizing (a) the construction of the additional polymerization facilities and styrene capacity, to be ready by January 1, 1944, which are required to balance upwards the annual production of the refinery-conversion program (110,000 tons of Buna S); and (b) the later construction of a 27,000-ton butadiene plant and a 30,000-ton polymerization plant to be located near the center of grain production. The committee recommends that the rubber administrator, about six months hence in the light of the situation which exists regarding the best technical process then proven for the production of butadiene from grain, and in the light of the need for additional Buna S which may then be estimated, proceed with the erection of the 27,000-ton butadiene plant from grain and the associated polymerization plant. He should also make whatever arrangements are necessary to produce and ship the necessary styrene from the centers of styrene production. If the needs for synthetic rubber and the production program are in balance, making due allowances for civilian driving, he may then cancel the erection of this additional 30,000 tons of Buna S capacity.

The Secretary of Agriculture has assured the committee that no concern need be felt that the expansion of the butadiene-from-grain program will interfere with our food supplies. After all food requirements that can be anticipated have been met there will be upwards of 1,250,000,000 bushels of wheat left in this country.

This additional Buna S, which it will be thus possible to produce in 1944, should provide the margin required for relaxing the restrictions on civilian driving. As we have pointed out earlier in this report, if by the end fo 1943 the synthetic rubber manufacture is in satisfactory shape and the military needs for rubber have not increased, it should be possible to allocate considerable quantities of Buna S for civilian needs. We shall not need the 140.000 extra tons of Buna S until 1944, when it will be required for tires for passenger cars. Without at least half this amount in that year, a great many passenger cars would be forced off the road; for it is at that time that we shall have to begin to repay the rubber which we have been borrowing, so to speak, by running our cars without a tire replacement and recapping program during the past eight months.

By delaying the construction of the extra polymerization facilities for six months we shall in all probability prevent a serious conflict between this eventual expansion of the Buna S program and other aspects of the war program. There is every reason to believe that the shortage of critical materials will be less acute six to eight months from now, and this will certainly be true in regard to facilities for fabricating special chemical equipment.

Our recommendation for additional 27,000 tons of butadiene capacity to be located near the center of grain production is made with this time schedule in mind. This plant (together with the corresponding 30,000-ton Buna S plant) need not be started for another six months. There will be relatively little cost to the war effort involved in its construction for the reasons just given in regard to the easing of the situation in respect to the fabrication of equipment. Furthermore, another advantage will accrue. At that time—six months hence—it will be possible to judge the relative merits of two processes for the manufacture of butadiene from grain which are not now in the government program, namely, the Publicker process using alcohol and that employing butylene glycol developed by the Department of Agriculture in Peoria. This latter method involves a special fermentation of grain. These two processes should be carefully compared with the alcohol process developed by Carbide and Carbon Corporation and now a major part of the government's plans. At present insufficient data are at hand for an evaluation. A few months from now this will no longer be the case.

It is clear to the committee that new facilities for producing alcohol from grain must be provided. More alcohol may be required for the production of butadiene in plants under construction, if not, the extra capacity will be useful in the explosives program. The estimates we have obtained from the most reliable sources vary, but in all likelihood a considerable quantity of additional alcohol must be on hand in 1943 and 1944 to meet both the synthetic-rubber and the explosives program. We recommend that these facilities be erected on a site near the grain-producing states and located on water transportation. By the use of recently developed apparatus, alcohol plants can be constructed with little expenditure of critical materials.

If the rubber administrator should decide that the plants for the production of the additional 30,000 tons of Buna S which we recommend should be constructed during late 1943, they should be located near the center of grain production and such units should if possible be operated under the control of an independent local group. Diversification of the synthetic-rubber industry both from the point of view of geography and control seems important to the committee. Another element in the competition would be provided if this recommendation is carried out.

We may sum up our recommendations in respect to the Buna S program as follows:

(1) There should be no further changes in the plans now laid for the construction of the scheduled plants—the time to freeze has passed in view of the urgency of 1943.

(2) The authorization of an additional 140,000 tons of Buna S capacity per year.

(3) Proceed immediately with a conversion of refinery plants to produce a total of 100,000 tons of butadiene by this process, this being in addition to the butadiene now planned from other processes in the present program.

(4) Promptly make an adjustment in the construction rates of the present styrene and polymerization plants, in order that the maximum amount of Buna S may be produced in 1943.

(5) Expand the polymerization and styrene facilities to be ready on January 1, 1944, to balance upwards the entire program.

(6) About six months hence, in the light of the situation which then exists regarding the best technical processes then proven for the production of butadiene from grain, and in the light of the need for additional Buna S rubber which may then be estimated, proceed as indicated with the erection of a plant to produce an additional 27,000 tons of butadiene from grain through alcohol or butylene glycol and with the erection of an associated additional polymerization plant to produce 30,000 tons of Buna S, both to be located near the center of grain production. Also make whatever arrangements are necessary to produce and ship the necessary styrene from the centers of styrene production.

(7) Proceed promptly with the erection of an alcohol plant to produce 100,000,000 gallons of alcohol per year, by the use of recently developed apparatus. This plant could be erected on

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a site near the grain producing states and located on water transportation.

Finally, as a further margin of safety, considered only from the point of view of filling military needs, we recommend the construction of an additional plant for the production of neoprene to the extent of 20,000 tons a year capacity. We make this recommendation because neoprene is the one synthetic material of a quality to be the full equivalent of natural rubber for combat and heavy-duty tires, either by itself or in combination with Buna S.

The relatively high cost of this substance in terms of critical materials required for the construction of the plant and electric power needs is offset by its special significance in the rubber program. As an insurance against the distant possibility that we may be cut off from all supplies of natural rubber, we feel that the expenditure involved to provide an additional margin of safety is not too great.

Four large rubber companies already have developed their own polymerization facilities, each one differing somewhat from the others. Each represents the best efforts of a separate group of keen technical men. Last May, Rubber Reserve decided to standardize all the new polymerization plants which were to be constructed; this means, in essence, also standardizing the operation.

The design that is now ready is a compromise of the ideas of four separate technical groups. It may or may not incorporate the best ideas of each; on this point grave doubts have been expressed to the committee. At all events, no one has ever operated such a standardized plant. The need for the immediate construction of one such standard plant so that experience with its operation can be obtained at the earliest moment is evident. It is our recommendation, therefore, that one of the standard plants now on the schedule be rushed to completion as quickly as possible.

The recognition of the importance of technological competition leads us to make two recommendations in regard to the operation of the polymerization plants:

First, one or more corporations controlled by the smaller rubber companies and chemical companies interested in polymerization should operate a certain number of these standard plants.

Second, at the same time, to keep the competitive urge to improve the new art of polymerization, we recommend that as part of the program each of the four large rubber companies be allowed to expand their facilities according to their own design, if they so prefer. We feel sure that the pride of authorship, as strong among technical men as among artists, under these conditions will yield in a short time a rich harvest to the nation. Adoption of this second recommendation would not retard the program, for the expansion should be provided in that portion of the program we have recommended which requires additional polymerization facilities to be ready about January 1, 1944, to balance the refinery conversion program.

The nation as a whole is endeavoring to provide for the development of essentially novel manufacturing operations on a vast scale. How this program is managed and the spirit in which it is carried forward seem to us of great significance. Unlike the production of ammunition, the enterprise has implications for the postwar period. For a double reason, therefore, the nation is concerned lest special groups play too large a part in the construction and operation. For the rapid development of the new art this committee is fearful lest the influence of governmental policy serve to discourage the beneficial rivalries of the best brains in industry. We believe, therefore, that on the one hand there should be complete interchange of information and, on the other, as much competition in research, development and operation as possible. Such, after all, are the conditions applying in the field of laboratory science where during the last hundred years tremendous strides have been made. Competition and cooperation in this national effort, we believe, should go hand in hand.

In concluding this section of the report which deals with the synthetic program, the committee wishes to make special mention of the fact that there are a number of materials in the offing which give promise of considerable significance in the future development of rubber substitutes.

In particular, flexon, which is very similar to butyl rubber, is now undergoing careful tests to determine its utility in the manufacture of tires and as a recapping material. Flexon has an advantage over butyl rubber, in that it can be made more quickly and the plant involved does not require any large amount of critical materials.

The production would be limited, however, by the amount of solid carbon dioxide (dry ice) that would be available. The process is a wasteful one from the point of view of isobutylene, a raw material which is also of great value to the aviation-gasoline program. As the tests of flexon stand today, the committee does not feel that it can recommend the inclusion of any large production in the present program. However, in the course of a relatively short time the art of manufacture may be improved and one of the chief present drawbacks, namely, the lack of uniformity in different samples, may be overcome. If later tests prove the usefulness of this substance, its production then could be undertaken in considerable quantities.

Another rubber substitute which we are not recommending in our program but which is nevertheless in an interesting state of development is the material known as "noropol," prepared by a series of chemical reaction from soya bean oil. The process of manufacture seems entirely feasible, but the tests have not yet gone far enough to demonstrate the worth of the material in the manufacture of tires or recaps. It will undoubtedly have value as a substitute for rubber in certain mechanical goods.

Several other developments of a similar nature have been called to the committee's attention, but all are as yet in the laboratory stage. The committee hopes that experimentation will continue and facilities be provided so that these new substances which show real promise may be tested thoroughly and eventually find their proper place in the national economy. Necessity requires the country to stop tampering with the present synthetic rubber program in order to produce the maximum amount of usable material in the coming year. It would nevertheless be most unfortunate if this situation should prevent the development of other materials or new methods of manufacture.

7. Priorities

The committee wishes to emphasize and reemphasize the absolute necessity of having the maximum amount of synthetic rubber produced in the year 1943. As we have said before, this turns largely on the rate of completion of the plants now scheduled. No one of these plants of any considerable capacity has been completed as yet. Many of them are not yet even started. We have found that although there is every reason to believe the construction schedule can be met so far as the time of fabrication and construction is concerned, there is grave doubt whether the plants will actually be erected as planned unless something is done at once to change the situation in regard to the flow of materials to the fabricators.

We therefore recommend that urgent attention be paid to this phase of the rubber problem. We already have pointed out the dangerous situation the country would face if even four months of delay in the program should occur. Indeed, it is clear that the whole problem of critical materials is intimately associated with the problem of producing sufficient synthetic rubber in 1943 to tide us through the crucial year, and the President has asked us to make a report on critical materials.

Much has been said of shortages in critical materials. There are two kinds of shortages: the first where there is not enough to go around for essential purposes; the second type of shortage is that where though sufficient exists, it is short in the sense of not being available when and where it is urgently needed. There are a few materials short in the first sense, but many have been short in the sense of failing to be where needed when needed.

This has been due to permitting materials to be used for purposes not essential to the conduct of the war; to the lack of a vigorous policy of conservation, inventory control and the finding of substitutes; and most of all, to the changing, complicated and ineffective efforts at material distribution and priority control.

Shortages have been accentuated by superimposing upon the heavy military demands and delayed conversion of civilian industry to war purposes, a vast war construction program approximating seventeen billion dollars. This program will be nearing completion by the end of this year and will thus release large amounts of construction materials. It is estimated that 70 to 80 percent will be finished about January 1, 1943, and all about July 1, 1943.

After this, provided vigorous measures are taken to increase supplies, find substitutes, press research work, complete the process of conversion, effect the utmost in conservation, inventory control, standardization and simplification, and above all to perfect a simple, sound and workable system of priorities for the distribution of materials, unless demands are greatly increased, shortages should be much reduced and the bottlenecks in critical materials become fewer.

There has been often an attitude of complacency and a failure to take the vigorous measures necessary to increase supplies, working closely with the industries concerned. There has been some disposition to accept the "impossible" instead of trying to overcome it.

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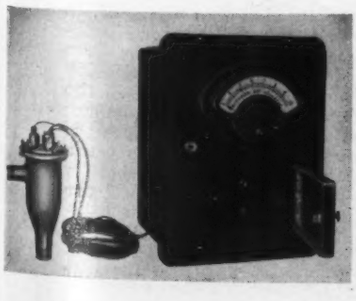

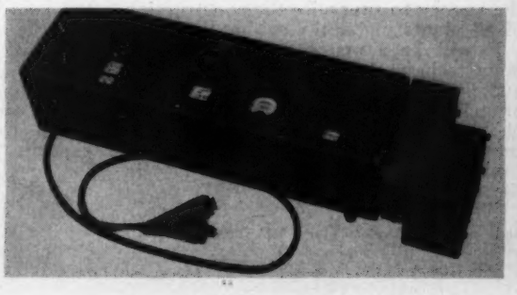

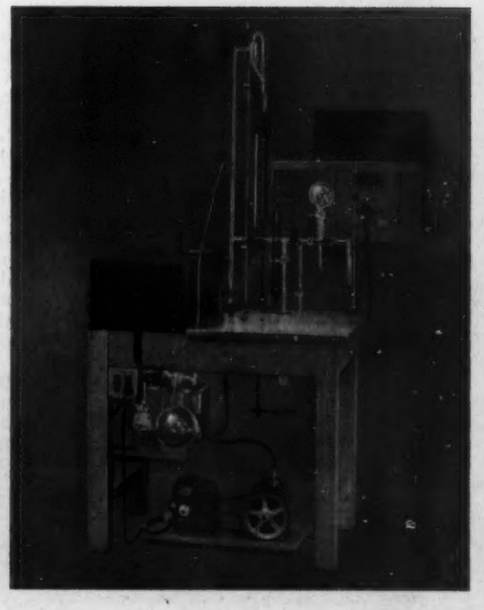

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but it is the duty of this committee to point out that unless the flow of materials for the construction of these synthetic rubber plants is insured there will be no rubber in the fourth quarter of 1943 with which to equip a modern mechanized army.

8. Administration

The committee finds that a number of different government agencies have had overlapping jurisdiction in regard to the synthetic-rubber program. This has caused delay and confusion. In particular the conflict between Rubber Reserve and OPC has complicated in recent months the bringing in of new facilities for the production of butadiene from oil. The committee has been unable to determine, in spite of many inquiries, as to where the responsibility has lain for many of the decisions which have been made in the last eight months.

The failure of the government to provide a clearly recognized group of independent experts who would make technical decisions has added greatly to the public confusion and uncertainty. The reliance on one part-time technical adviser, added by committees drawn from industry has, in the opinion of the committee, been insufficient for the development of an entirely new industry involving an investment exceeding $600,000,000. The technical adviser has testified that on more than one occasion he requested the appointment of an adequate technical staff.

It would have been wise administration for the officials in charge of policy to have delegated to a competent technical staff the function of collecting information about the various processes. Such a staff should have been relied upon for supplying through regular channels the data on which all important decisions were made. Instead of such orderly methods of procedure we have found many evidences of a chaotic situation in which non-technical men have made decisions without consultation with subordinates nominally in positions of responsibility.

There have been many adjustments and readjustments—a "stop-and-go" policy—in the synthetic-rubber program. Some of these were inevitable; some appear to be the result of bad administration.

There is clear evidence that the situation with respect to the alcohol supply was altered between the fall of 1941 and the spring of 1942. What had once been a deficiency became an apparent surplus. As a result of this change the proportion of alcohol and petroleum-based processes in the synthetic-rubber program was altered. A more adequately staffed organization might have foreseen earlier the changed situation and altered the program a few months earlier.

As another example of faulty administration we may mention the failure to obtain early in this year the detailed information concerning the Russian process for making synthetic rubber. Russia has been manufacturing synthetic rubber successfully for more than ten years. It would seem natural to have endeavored to benefit from this experience as soon as rubber became of major concern to the United States. If the Russian offer made in February to exchange men and information had been accepted and Russian engineers with blueprints of manufacturing had been rushed to this country last winter, it is conceivable that plants for producing synthetic rubber by the Russian process might well be now on the way to completion. To date we have no detailed information as to the process and no samples of Russian tires have as yet been obtained. Every effort ought to be made to obtain this information.

The dissemination of full information concerning the compounding of Buna S to all companies has become an accomplished fact only in the last few days. An agreement was entered into on July 3 of this year between Rubber Reserve Company and four large rubber companies. According to this agreement, Rubber Reserve alone was permitted to give out information to the other rubber companies. But in fact it did not do so for some six weeks in spite of repeated efforts of the Rubber Branch of WPB to have the information released. In view of this situation one hardly needs to point out that there has been very imperfect cooperation between the Rubber Reserve Company and the Rubber Branch of WPB.

Because of the record briefly summarized above, we recommend:

A complete reorganization and consolidation of the governmental agencies concerned with the rubber program.

The War Production Board must assume full responsibility for the rubber program in all of its phases. We therefore recommend a directive from the President ordering the Rubber Reserve Company and all other government agencies to act in all matters relative to the rubber program as directed by the chairman of WPB.

To discharge adequately the responsibilities which we recommend that the chairman of WPB explicitly assume for the entire rubber program, full authority must be centered in a single official. We therefore recommend that the chairman of WPB appoint a rubber administrator and delegate to him full and complete authority in regard to the manufacture of synthetic rubber, including research, development, construction and operation of plants. This single official, who must be a man of unusual capacity and power, must also have full charge of all matters connected with rubber within the WPB. It should be his duty to formulate policies and administer the operation of the rubber program subject only to the chairman of WPB, who should divest himself of all direct concern with these matters. Good administration dictates that the rubber administrator use the available facilities of other government agencies in the execution of the program, but his decisions and not theirs must control.

We recommend that particular care be directed to the establishment of a technical division, under the immediate control of the rubber administrator. We also recommend that the construction division of Rubber Reserve be designated by the rubber administrator as the agency to supervise the construction of all plants under the rubber program.

It will be a matter of great importance to have the technical division adequately staffed and provided with branches in charge of all the various phases of research and development, except for the production of butadiene from petroleum which is referred to in the next recommendation.

The rubber administrator, acting on authority delegated by the chairman of WPB, should have the sole responsibility for supervision of operation of all government plants engaged in the production of rubber. In the execution of that responsibility he may utilize other agencies of the government upon their agreement thereto, but shall not be required to do so, and he shall cancel such arrangements when satisfactory results are not obtained.

Funds must be made available at once to WPB to provide for the staff under the rubber administrator and to enable him to place such contracts as he may deem necessary in connection with research and development.

We further recommend that the petroleum coordinator be directed by Presidential order to act on specific directives from the chairman of WPB, acting through the rubber administrator, to explore all methods for the production of butadiene from petroleum and natural-gas products and recommend new proposals to the rubber administrator for his consideration and action.

The construction of all plants and equipment concerned with the production and purification of butadiene from petroleum should be under the authority of the rubber administrator, who we recommend shall designate the construction division of Rubber Reserve to carry out this function.

This provision is necessary in order to unify control of the construction program and make certain that no delays ensue by reason of conflicting authority and personalities. The petroleum coordinator should have supervision of the operation of the plants for the manufacture of butadiene from petroleum and natural-gas products after completion of construction, but he should be directed not to modify the presently authorized construction program or the plans for operation except as approved by the rubber administrator.

We further recommend that in the Office of Petroleum Coordinator there be created a new technical division responsible for research and development in connection with all problems of the manufacture of butadiene from petroleum; funds for this purpose should be provided to OPC.

This specific delegation of responsibility to the petroleum coordinator is made in order to secure complete coordination of the butadiene program with other petroleum and natural-gas requirements, especially for aviation gasoline and for toluene for explosives.

As the situation develops it may be desirable for the funds required for the entire rubber program to be put directly at the disposal of the chiarman of WPB for the purposes of the rubber administrator instead of, as at present, indirectly through RFC.

The most important part of the plan is obviously the choice of the right man for the position of rubber administrator. He should be a thoroughly competent operating and manufacturing executive, preferably with experience in the rubber industry. The demand for speed and the vital need for this man to start with experience and knowledge of the problem make it important that the man chosen be of proven integrity and enjoy the public's confidence and that of the rubber industry as well. We cannot stress too much the importance of choosing the right man for this work, for no plan of organization can bolster up a weak man sufficiently to meet the difficult problems he must face.

One of the problems presented to this committee has been the difficulty of determining the future needs of the war

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program for rubber and the components required for the manufacture of synthetic rubber and substitutes. This difficulty arises from the unpredictable character of the war operations as to location, kind of war, and equipment employed under various conditions. In spite of these and other such difficulties, there is need for determining the requirements on an authoritative basis. Every aspect of the rubber problem must be under continuous review by a man whose sole responsibility it is. The most we can do is to appraise the present situation and indicate a sound course for the future.

A program can be no better than its administration; therefore we place special emphasis upon these series of recommendations and wish to state that unless they are followed there can be no assurance of the successful development of the synthetic-rubber program within the time required.

9. Agricultural Program

Various plants which can be grown in the United States have been suggested as sources of rubber. Thomas Edison's experiments with goldenrod are an example. Kok-saghiz, a Russian dandelion, is considered promising in the U. S. S. R. as an auxiliary source of rubber, and seeds have been sent to the United States for test planting. However, the two agricultural possibilities which show most promise for the United States are guayule and cryptostegia.

Guayule is a shrub which grows freely in Mexico and the American Southwest. It contains a high percentage of rubber which is extracted from the entire plant. Best yields are obtained after four years' growth, but the shrub can be harvested any time after two years.

The Department of Agriculture has undertaken a large program of guayule cultivation in California, based on an initial independent planting of 500 acres in 1930. With seeds on hand and the expected harvest this month, there will be 66 tons of seed available for further planting. The seeds must be planted in a nursery and after one year transplanted to the field. The plans call for planting an acreage increasing to about 180,000 acres by the end of 1944. If this program is carried through, it is anticipated by the department that there will be crude rubber available from this domestic guayule rising from 600 short tons in 1942 to about 33,000 in the fall of 1944, about 47,000 tons in the fall of 1945, and increasing thereafter.

The committee believes that these estimates are over-optimistic but that the project is inherently sound and should be supported. The committee therefore recommends that this program be given every possible support as the principal source of crude rubber which could not be lost to us short of conquest of American territory. In order to proceed with this program, however, certain things must be given immediate attention since the program will be delayed one year unless the following actions are taken before about October 1.

(1) Authorization must be secured to plant additional acreage. There is a question as to whether or not existing legislation would prevent the planting of more than 75,000 acres of guayule. This restriction, if it exists, must be removed very promptly if the program is to go forward on a really significant scale.

(2) The second item is the procurement from WPB of adequate priorities to secure the amount of farm equipment which would be required to prepare the land and plant the seeds. This, again, must be done very promptly to meet the fall planting season.

There are additional requirements for the success of the program, which are sought by the Department of Agriculture and to which the committee gives its support.

Cryptostegia is second in importance among rubber-producing plants capable of substantial scale production in the United States. This vine will grow wild in Florida and other Southern states. It contains only two or three percent of rubber, but this is of high grade and can be secured from the leaves harvested each year from the perennial vines. A plan to plant these vines extensively this year has met with relatively small success, owing to a delay in securing authorization for the gathering and purchase of cryptostegia seeds from wild-growing vines in Mexico. This authorization was another instance of "too late," and was secured just after the seeds had scattered. There is little to be lost and much might be gained by pursuing this program vigorously when the next opportunity arises next year.

10. Rubber Goods Manufacturing Capacity

A very important consideration in connection with the synthetic-rubber program has to do with the capacity of the country to manufacture rubber goods out of the natural and synthetic

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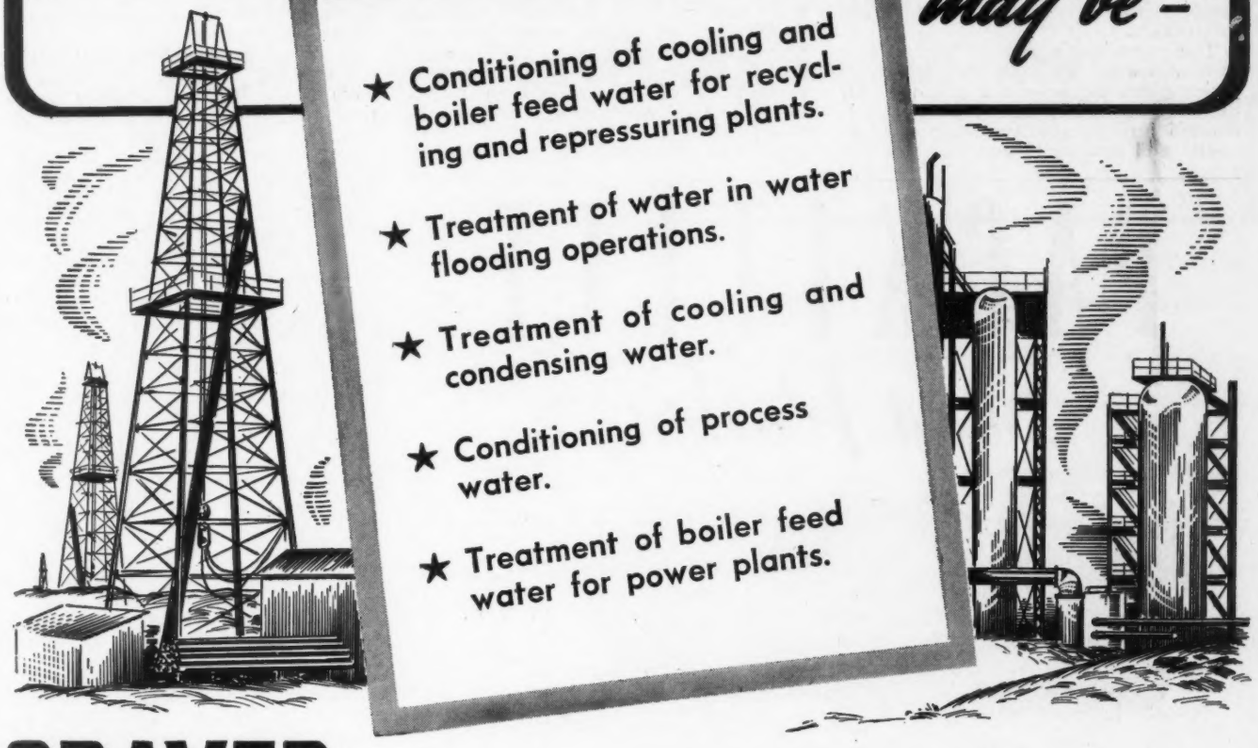

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rubbers which will be available. It would be obviously foolish to carry through a program of plant construction for the manufacture of synthetic rubbers only to discover too late that the factories for the manufacture of tires, electrical insulation, footwear and other rubber goods have insufficient manufacturing capacity to handle the material. The committee has made a survey of these facilities and finds that, as matters now stand, there may indeed be a deficiency of factory capacity to handle the synthetic rubber when it comes into full production.

The committee's findings and recommendations in the matter of manufacturing-plant capacity are given below under three headings: rubber goods manufacturing capacity, recapping capacity and reclaim rubber capacity.

(a) *Rubber goods manufacturing capacity.* The significance of this problem is indicated by the following facts:

(1) The largest previous year's use of rubber goods in the U. S. was 775,000 tons of crude rubber in 1941.

(2) The largest monthly production in the history of the rubber manufacturing industry used at the rate of about 1,000,000 tons per year of crude rubber —a rate which could not be continuously maintained.

(3) The present governmental program calls for the procurement of about 68,000 tons of crude rubber and approximately 910,000 tons of synthetic rubber substitutes in 1944. The recommendations of this committee would raise the total of these synthetic materials to about 1,100,000 tons.

(4) The processing art as developed at present requires more time, on the average, to fabricate than for the same tonnage of natural rubber. The committee estimates that, on this account, the manufacturing capacity today for synthetic rubber is between two thirds and three fourths of what it would be for handling natural rubber.

These facts would indicate that the capacity of the country would have to be increased substantially to handle the quantities of synthetic rubber which will be produced in 1944. However, the following compensating factor must be taken into account:

(5) During recent months technical developments in the processing arts have proceeded very rapidly and the time required for the manufacture of synthetic goods is being reduced. For example, during the short existence of this committee, means have been found for doubling the speed with which milling and mixing operations can be performed with butyl rubber. Similar advances are being made in handling the other synthetic rubbers. There is reasonable expectation, therefore, that the intensive technical research program, now being carried on by the rubber companies, will substantially increase the speed with which synthetic rubber goods can be manufactured and therefore increase the manufacturing capacity of the factories.

For this reason the Committee recommends that the rubber administrator institute a survey of milling, mixing and tire-building facilities, on about March 1, 1943. This survey should determine the extent to which these facilities must be expanded in view of the processing and tire-building art at that time so as to handle the expected volume of synthetic rubber in 1944, after allowing for export of rubber stocks.

The committee is informed by the rubber manufacturers that a decision on this matter made by April of 1943 would permit the manufacturing companies to add whatever additional manufacturing facilities might be required, in adequate time to meet the manufacturing schedules of 1944—provided the necessary priorities are given for the procurement of the necessary equipment.

(b) *Recapping facilities.* The total recapping capacity of the United States, exclusive of the tire-building facilities of the tire manufacturers, is approximately 16,000,000 passenger-tire recaps per year. This might be increased to 19,000,000 by operating at full capacity with extra shifts. The program recommended by the committee for tire replacement and conservation may call for as many as 25,000,000 recaps per year. To meet this deficiency the committee recommends utilization of tire molds of the tire-recapping plants so as to meet any excess demand for tire recapping.

(c) *Reclaim rubber capacity.* The program of recapping for the conservation of civilian passenger tires, contemplates principally the use of reclaimed rubber. Other essential uses of rubber goods also call for reclaimed rubber. The armed services have gone far in substituting reclaimed rubber for natural rubber wherever circumstances permit, as a measure for the conservation of crude rubber. All of these demands for reclaimed rubber will somewhat exceed the capacity of the present rubber-reclaiming plants of the country and indicate the necessity for providing some increase in this capacity.

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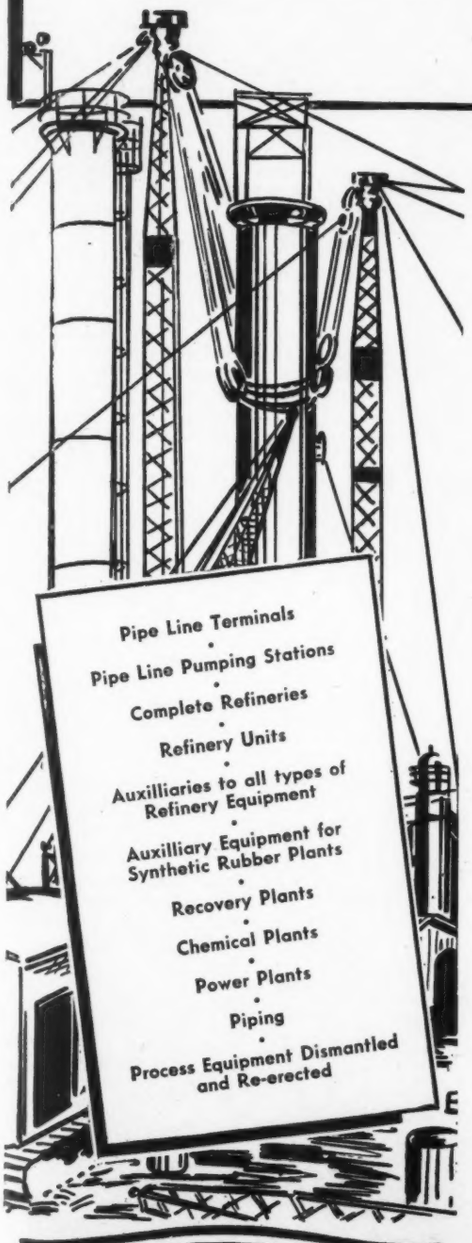

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of securing increased rubber-reclaiming capacity is by working through the existing experienced reclaiming companies rather than by erecting new and independent reclaiming facilities to be operated by a relatively inexperienced group.

The committee therefore recommends that the reclaim-rubber manufacturers, through their National Rubber Reclaimers Association be requested to submit to the rubber administrator a program for increasing by about 20 percent of the present rubber-reclaiming facilities of the United States, and that authorization be then given to carry through such measures as may be necessary in the form of priorities, financial aid or contracts to secure this increase in rubber-reclaiming capacity during 1943.

Several methods have recently been reported for increasing the useful qualities of reclaimed rubber. At least one of these is reported to involve only the use of chemicals which are not difficult to obtain in the present war economy. The committee recommends that every encouragement be given to the further development and application of these new processes. Such encouragement could take the form of priorities for procurement of the necessary experimental materials and also financial aid, if necessary.

11. Scrap Collection

No one can estimate with certainty the amount of scrap rubber in the United States. A reported 450,000 tons of scrap rubber were collected in the drive inaugurated by the President last June. This gross tonnage should yield about 350,000 tons of reclaimed rubber, but there is reason to believe that the actual amount of scrap collected is considerably below the above figure because of duplicated reporting of collections.

There have been sensational claims regarding the amount of scrap rubber still uncollected in the country. The committee has investigated some of these claims and has found them utterly without foundation in fact.

It is nevertheless true that the rubber now in the scrap piles of the country, together with anticipated current receipts, are sufficient to feed the rubber reclaiming plants at full capacity for about 18 months. During this time further scrap collections will continue through the normal operations of scrap collectors and junk dealers. In addition to this supply the armed services have instituted, as part of their program of rubber conservation, an inspection system which will insure that damaged tires from military vehicles will be repaired if possible, and if not capable of repair will be assembled through scrap-collecting agencies and thus fed into the nation's scrap stockpile.

Still another supply of scrap rubber will come automatically if new tires are rationed to civilian drivers in accordance with the recommendations of this report, since a condition for the procurement of a new tire will be the turning in of the worn-out tire for scrap.

With these supplies of scrap rubber in sight there will be adequate time for the careful preparation of another national scrap rubber drive well in advance of serious depletion of the existing stocks. The committee recommends that this drive be carefully prepared in advance to secure its maximum effectiveness, and to this end suggests that the rubber administrator take the initiative in selecting and directing the proper agencies for the organization and conduct of this drive. The committee further believes that these steps can most advantageously be undertaken about a year hence.

Elsewhere in this report the committee makes a number of recommendations in regard to the increased production and more efficient use of the reclaimed rubber produced from this scrap.

12. Technical Suggestions for the Rubber Administrator

As a result of the study made by our experts the committee has been in a position to evaluate a number of technical points in connection with the rubber program. Therefore we have a number of recommendations to make of a minor nature which we should like to pass on to the man who, we hope, will be in charge of the rubber program as rubber administrator. We shall assume that he will immediately place a highly competent man on a full-time basis in charge of his technical division, and it is to that man in particular that these suggestions are directed.

1. We recommend the immediate installation of one or more small commercial pilot plants using the catalyst system developed by Standard Oil of New Jersey operating on butylene feed stock. These should be completed with fractionating towers and refining systems to the end that they may serve as training plants for the study of any difficulties that may be experienced in

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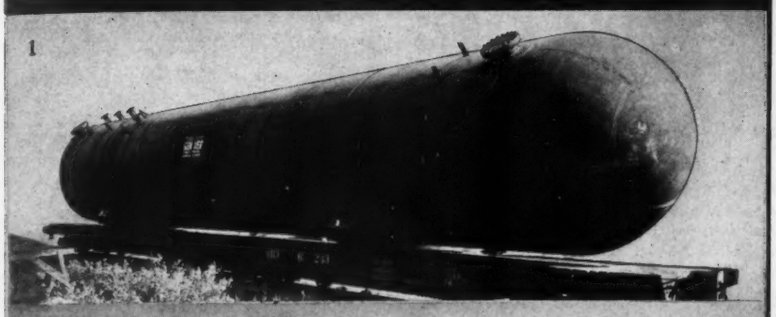

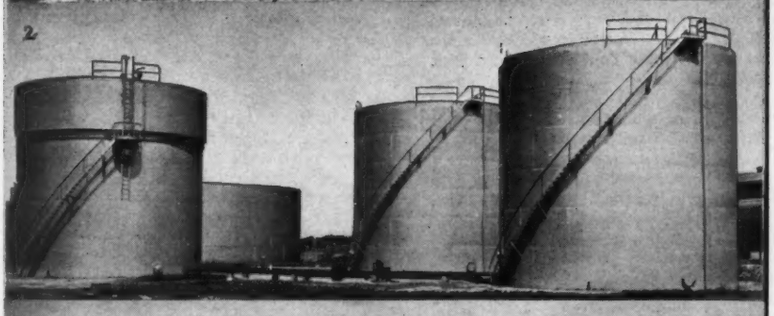

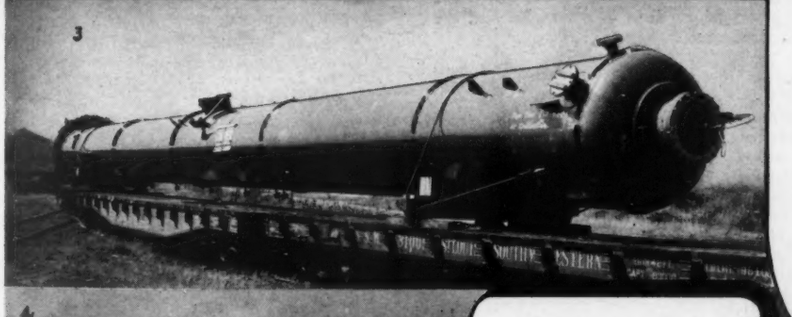

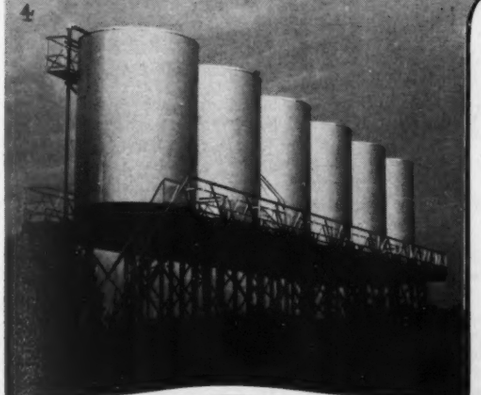

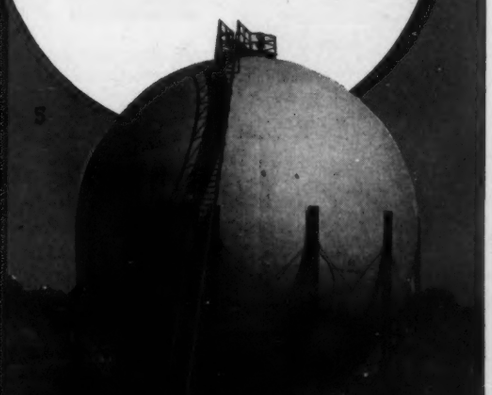

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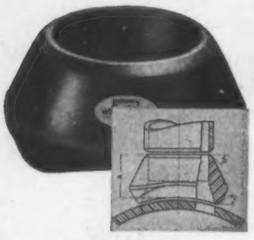

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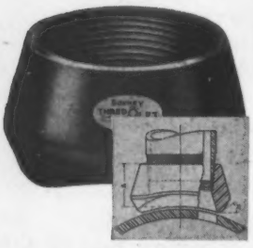

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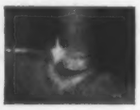
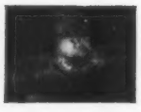
2 Tack in a sufficient number of places to insure its desired position. No clamps are necessary. Then weld, following and filling the bevel along the base of the fitting. A junction of full pipe strength results.

3 Then remove the button with the torch, a hole saw or by drilling. Where the outlet is smaller than 2" . . . or under unusual conditions on the larger sizes, the fitting should be used as a templet and the hole cut in the main pipe first.

4 After the fitting is installed on the main pipe and the button removed, the inside of the joint is in full view for inspection . . . impossible with a junction made in any other way . . . or with any other type of fitting. Icicles, scale and excess welding metal are eliminated. They are removed with the button.



5 The branch pipe is then attached to the outlet of the fitting . . . by welding, if a WeldOlet or Socket-End WeldOlet is used . . . or simply screwed into position if a ThredOlet is used.



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bringing the large units into operation at rated capacity, and for trying out suggested means for improving the over-all operations.

2. We recommend that one of the large-scale plants operating on this same process should be given as high priority rating as possible to insure that it is completed by March, 1943, so that experience may be gained on the full-scale operating of this plant. Although our experts have no doubt that the engineering data provided by the small-scale experiments are adequate for the design of the large plants, it is clearly a difficult and somewhat uncertain matter to make the transition to the full large-scale plant which must be operated.

3. We believe that the purification of butadiene deserves further investigation both in the laboratory and in the pilot plants.

4. The committee has explored new and novel substitutes for conventional rubber tires, largely through access to a very full survey of such devices conducted by a special committee of the Society of Automotive Engineers at the suggestion of the National Inventors' Council.

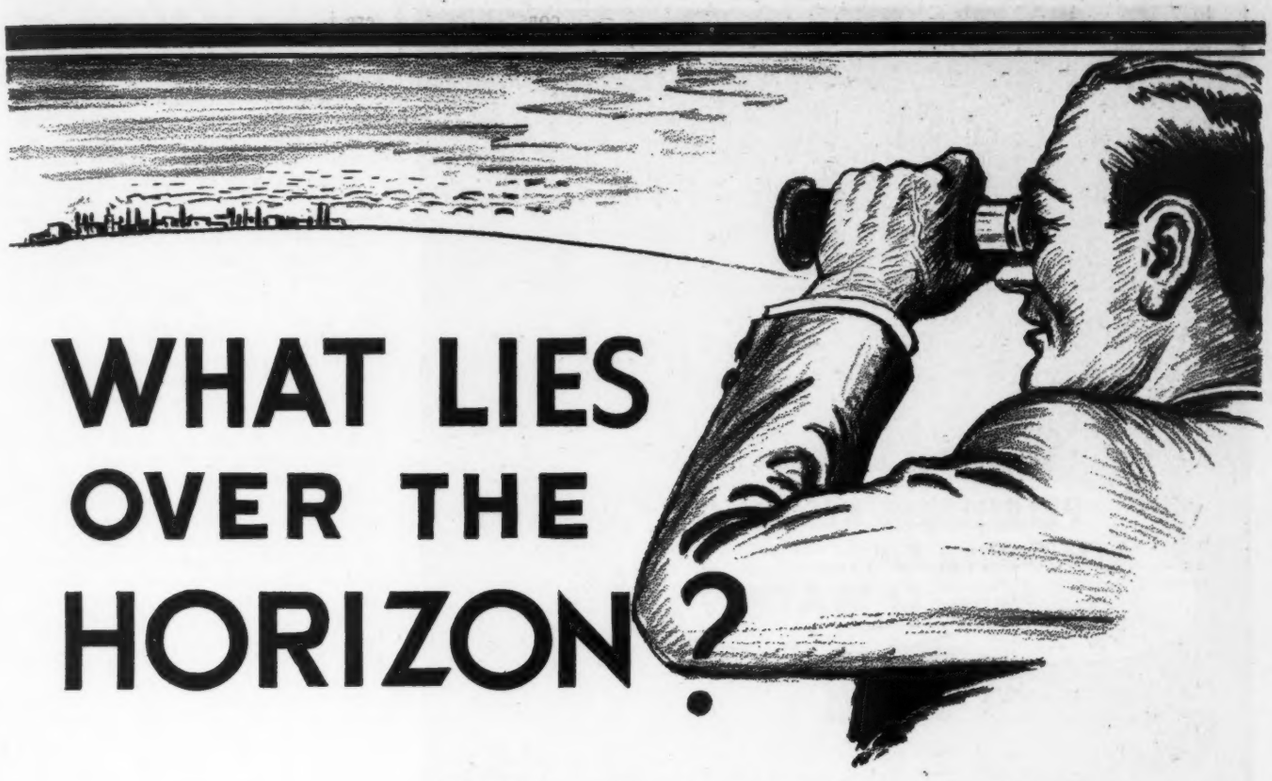
Among these devices one stood out as possessing promise of giving relief to the less essential drivers in urban areas during the next few critical years. It is the "sandal," developed by one of the large rubber companies, and consisting of a section of carpet impregnated with asphalt and easily fitted over an ordinary tire which has been too far worn to be used further with safety. On asphalt or concrete street, and at very moderate speeds, these sandals have a life of between 1,000 and 2,000 miles. Using no critical materials and easily manufactured, they may provide temporary relief to drivers who may otherwise be unable to continue driving their cars. The committee considers this to be an interesting possibility in the emergency and recommends that it be further studied.

5. The committee recommends that the policy of encouraging inventors and research groups working on the development of rubber or rubber substitutes should be adopted. This encouragement might take the form of granting priorities for critical materials, where the amounts required are not excessive, for experimental and pilot-plant development.

6. Recognizing the necessity for providing a real incentive to conserve crude rubber by finding ways of substituting synthetic, we favor the plan that was suggested by the Synthetic Rubber Section of the Chemical Branch of the War Production Board. This provided for a greater than proportionate increase in a manufacturer's synthetic rubber allocation if he could increase the percentage of synthetic rubber in his product.

Inadequate supplies of synthetics have forced postponement of this plan for the time being, but we suggest that it be reinstated in the program when large-scale production of synthetic rubber is attained. A further incentive for increasing the use of synthetics may be provided, within the limits of product specifications, by raising the price of crude relative to synthetic rubber.

7. Polyvinyl resins are now being used as rubber substitutes at a rate which corresponds to a saving of approximately 22,000 tons of crude rubber per year. Other substitutes are under



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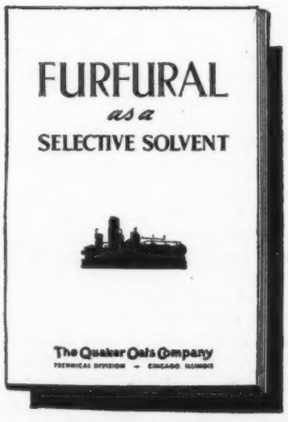

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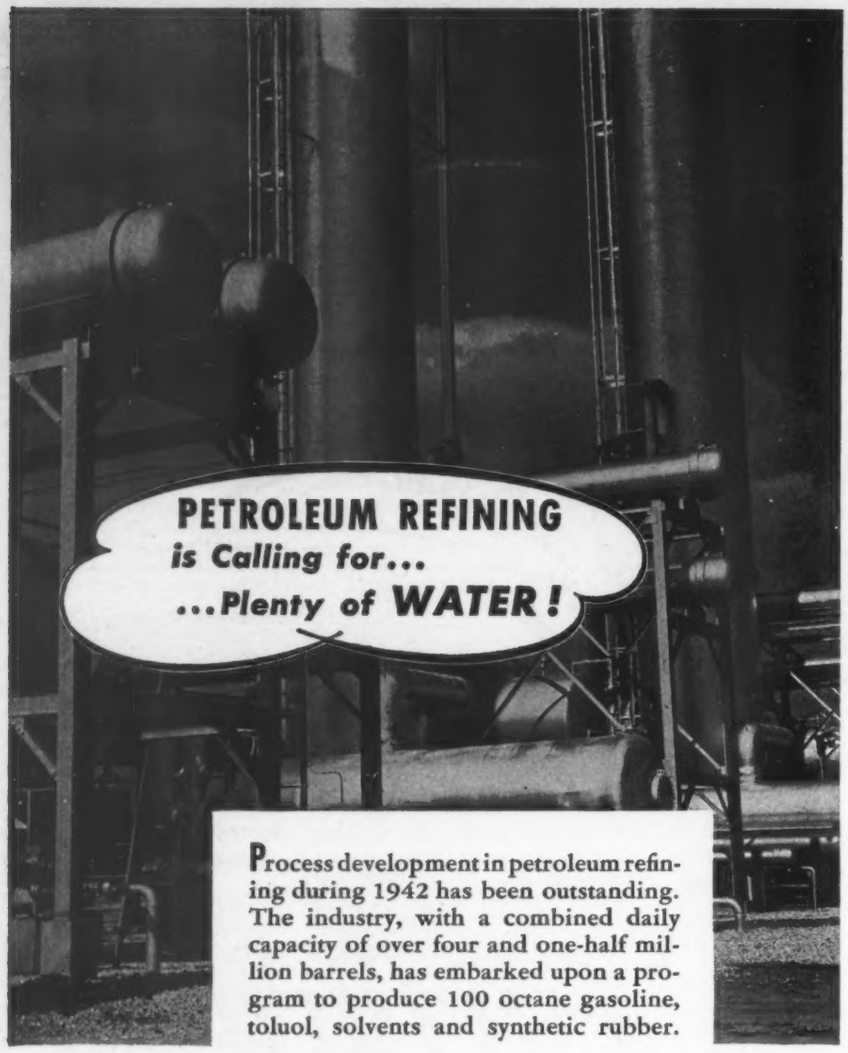

Process development in petroleum refining during 1942 has been outstanding. The industry, with a combined daily capacity of over four and one-half million barrels, has embarked upon a program to produce 100 octane gasoline, toluol, solvents and synthetic rubber.

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consideration, but there is no well-defined clearing house in any government agency at the present time for promising materials. Suggestions come in to Rubber Reserve Company, War Production Board, OPA and various other government organizations, but center at no definite point, with the result that there is duplication of effort and delay in evaluating such new materials. This should be centered under an official reporting to the rubber administrator.

8. There appears to be considerable confusion in regard to the military involving rubber substitutes. Several branches of the Navy and the Army each have been searching for rubber substitutes and are in competition with each other to obtain scarce materials. The rubber administrator should furnish the proper liaison for the armed services and should center research along these lines under his own control.

9. The committee suggests the institution of a prompt survey to determine the number of chemical engineers and other technically-trained men who will be required to operate the synthetic-rubber plants now under construction. And if this survey indicates a serious shortage of such technical talent, that the Manpower Commission be called upon for assistance in devising a policy for meeting the situation.

10. Inspections of a large number of crude and scrap-rubber stockpiles and examination of the methods being used for their protection have convinced the committee that this situation is generally satisfactory. A number of spots were found, however, where protection is definitely inadequate. While commending the inspection program now set up by Rubber Reserve Company, the committee suggests the advisability of more adequate protection through additional armed guards wherever a hazardous situation is found to exist. These stockpiles constitute some of the most critical possessions of the nation.

11. The committee also suggests the introduction into the manufacture of "camelback" for the retreading of civilian tires, the practice of adding up to 20 percent of finely ground tire treads into all reclaimed rubber tread stocks. This practice will improve the wearing qualities of the reclaimed rubber required for their production. This will be equivalent in its results to a further increase of between 10 percent and 20 percent in the capacity of the reclaim rubber plants.

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Pennsylvania Plant Under New Owners

The refining plant of Continental Refining Company, Oil City, Pennsylvania, has been sold and will continue to operate under its former name. New officials are A. B. Weingard, Butler, president; Todd K. Glenn, Leechburg, vice president; Benjamin G. McFate, Oil City, secretary and treasurer.

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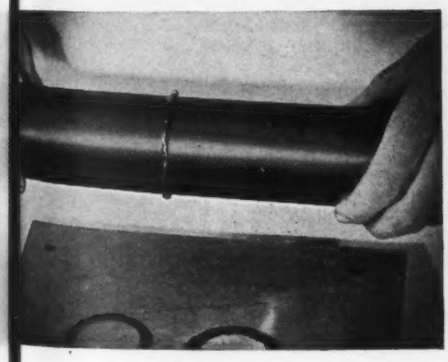

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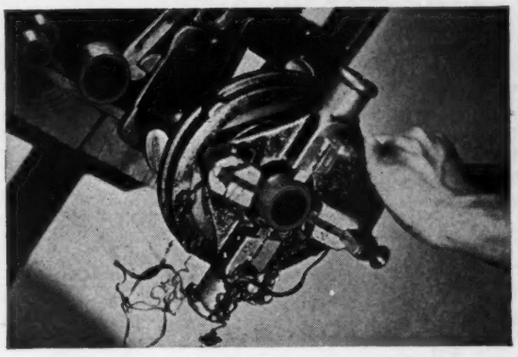

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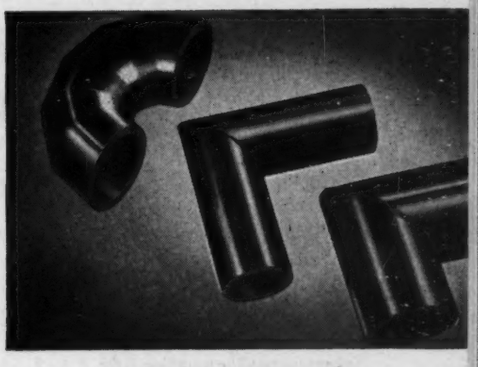

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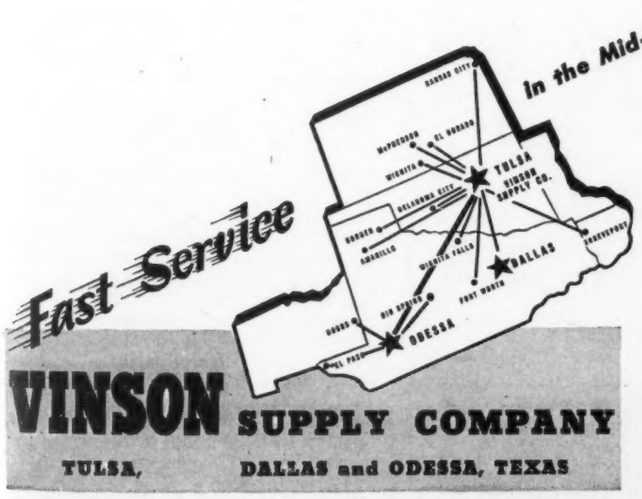

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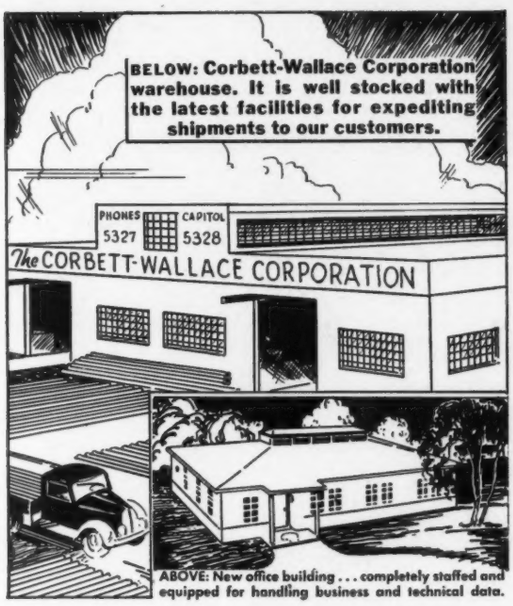
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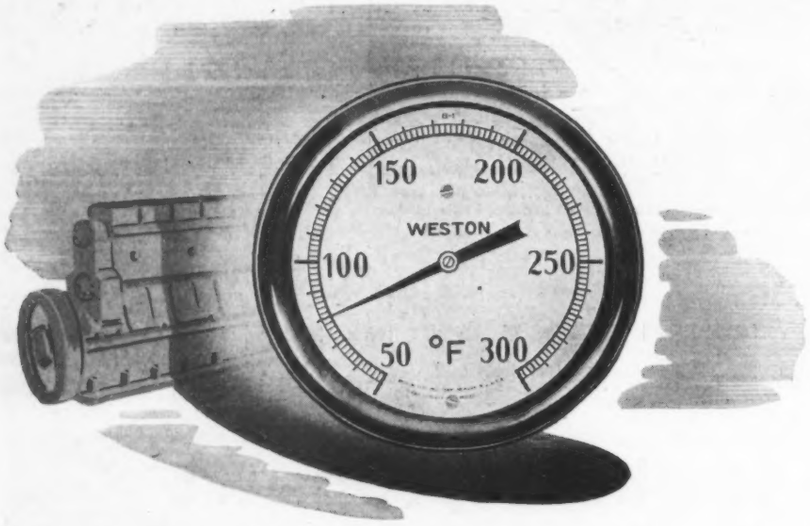

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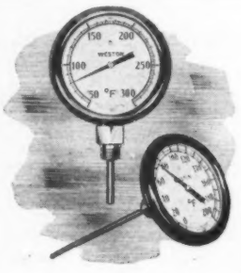

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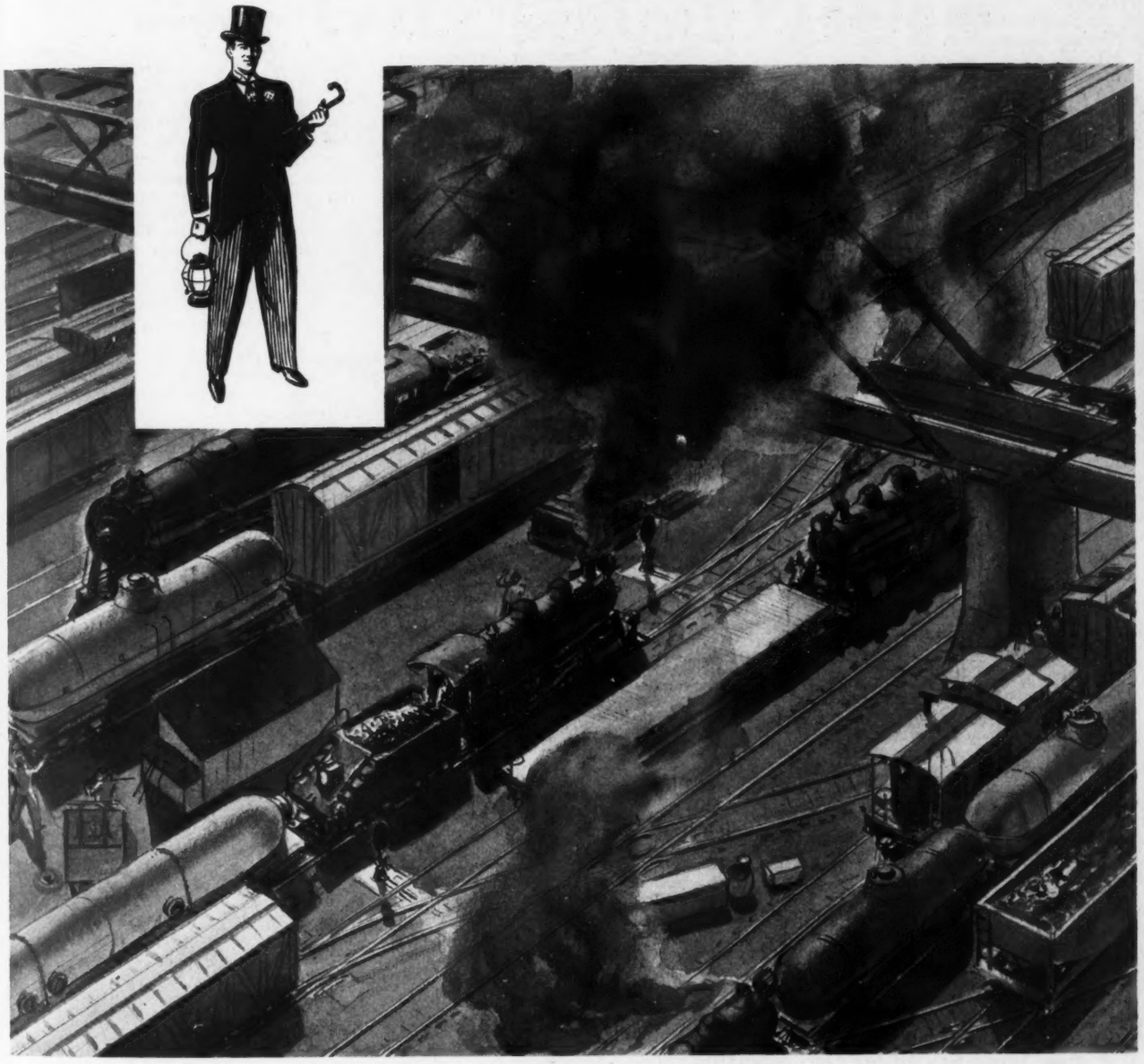

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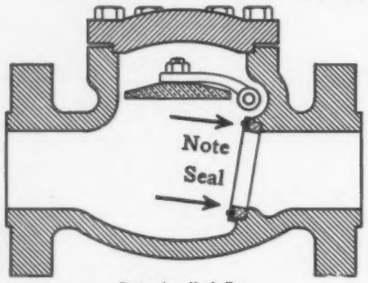

Pat. Applied For
API — FIG. R-102

These valves are identical with the standard Wheatley check valves except they are equipped with the Wheatley Synthetic Seal—a synthetic rubber ring dovetailed and fitted into a removable bronze seat also dovetailed to accept this rubber ring. When the bronze clapper falls against this rubber, a perfect seal is formed regardless of what irregularities have deposited on the seat or in the fluid, such as sand, scale and cuttings which ordinarily would cut a hard-surfaced seat completely out, with aid of pressure, of course.

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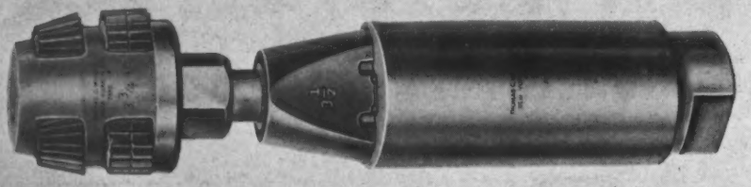

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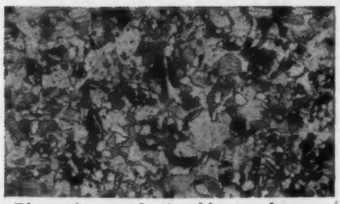

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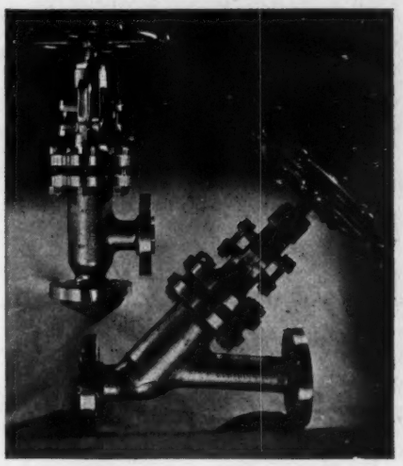

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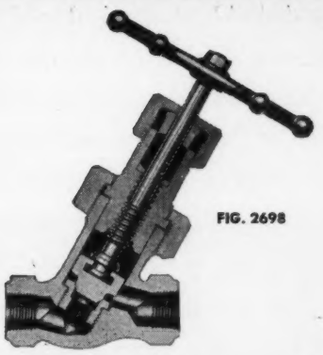

FIG. 2698

VERSATILE STOP VALVE . .

The best bet for a multitude of tough jobs —that's Edward Fig. 2698. Forged steel, inside screw, union bonnet, screwed ends. Full area, streamlined body minimizes pressure drop. EValloy seat and disk. Drop tight closure, easy operation. For 600 lb sp. at 750 F in sizes ¼ in. to 2 in. Fig. 2698 is globe, Fig. 2699 is angle. O.S. & Y. of similar design (Fig. 2688-9) also available.

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For tough blowdown jobs, count on Edward blow-off valves. Straightway or angle, shown above, for 150 to 1500 lb sp. Slow opening design avoids damaging shock to piping. EValloy or hard-surfaced seats and disks fight erosion and corrosion. Globe type seating design for tight closure with less leakage.

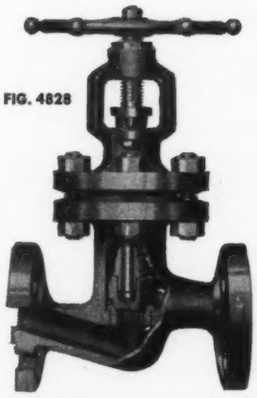

FIG. 4828

QUICK, SURE SHUT-OFF WITH EDWARD Fig. 4828 . .

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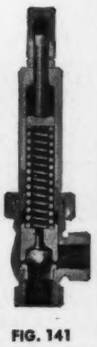

FIG. 141

INTEX STOP VALVE . . . . .

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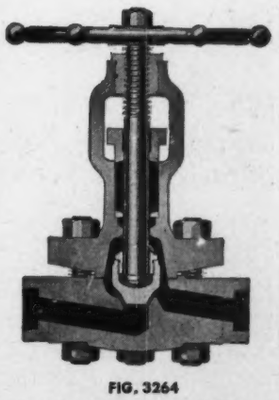

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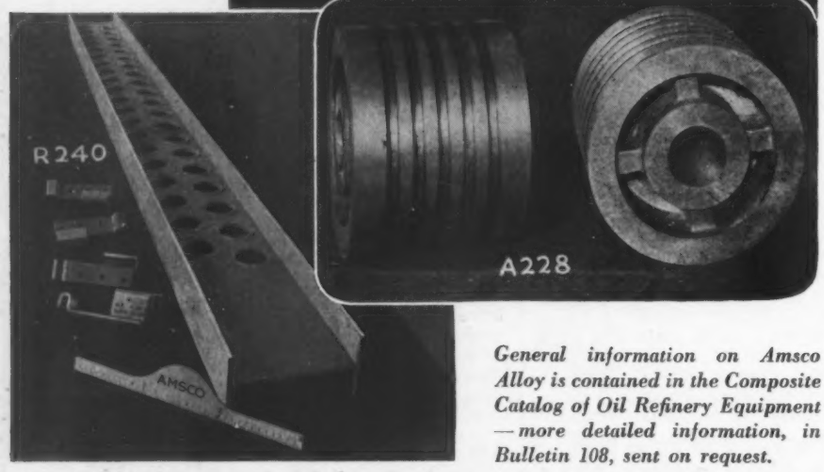

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Olefins, Diolefins and Styrene from Petroleum Products

U.S.P. 2,098,959. Hydrocarbon Conversion. F. E. Frey and W. F. Huppke to Phillips Petroleum Company.

For the purpose of a non-destructive dehydrogenation, hydrocarbons are brought into contact at temperatures above 325° with a vitreous gel catalyst comprising chromium oxide and a difficultly reducible oxide of aluminum, zirconium, titanium, silicium, thorium, boron or magnesium intimately mixed while the oxides are in a highly hydrous condition.

U.S.P. 2,110,833. Production of Styrenes. H. Mark and C. Wulff to I. G. Farbenindustrie, A.G.

Styrenes are produced by dehydrogenating one or more aromatic hydrocarbons having at least one aliphatic side chain with at least two C-atoms (ethylbenzene, isopropylbenzene, etc.). The vaporized hydrocarbon is diluted by steam or CO_2 and contacted at 500° to 700° C. with a catalyst comprising essentially a metal compound difficultly reducible to metal under working conditions which may contain from 1 to 3% of a metal compound reducible under working conditions.

U.S.P. 2,122,786 to 790. Dehydrogenation of Paraffin Hydrocarbons. H. Tropsch to Universal Oil Products Company.

Paraffinic hydrocarbons are heated to 300° to 700° in the presence of MgO, Cr_2O_3, and ZnO. A catalyst consisting of MgO containing a small proportion of chromate (lead chromate) may also be used. Al_2O_3 with a chromate and a sulfate, nitrate or acetate is another combination. MgO can be used with a small proportion of Cr_2O_3.

U.S.P. 2,126,817. Dehydrogenation of Hydrocarbons. R. Rosen to Standard Oil Development Company.

A catalyst such as Cr_2O_3 and Al_2O_3 on porous stoneware is contacted with hydrocarbons in the presence of an oxide of sulfur at a temperature above 340°.

U.S.P. 2,145,059. Production of Butadiene. R. Stadler, K. Ackerman and E. Lehrer to I. G. Farbenindustrie, A.G.

Butadiene is formed from vinylacetylene by contacting the latter at virtually any pressure or temperature with amalgams of alkali metals in the presence of substances which develop hydrogen with said amalgams. These substances consist preferably of the group consisting of water and alcohols.

U.S.P. 2,148,129. Dehydrogenation of Hydrocarbons. J. C. Morrell and A. V. Grosse to Universal Oil Products Company.

A Nd compound such as Nd oxides on Al_2O_3 is used as a dehydrogenation catalyst at a temperature of about 425° to 650° and for a time of about 0.5 to 20 seconds.

U.S.P. 2,148,140. Dehydrogenation of Paraffin Hydrocarbons. H. Tropsch to Universal Oil Products Company.

A catalyst mixture consisting of a major part of MgO and a minor part of a promoter such as a chromate, molybdate, aluminate, titanate, uranate, permanganate or perrhenate is used. Dehydrogenation occurs at a temperature of about 500°.

U.S.P. 2,152,908. Dehydrogenation of Hydrocarbons. J. C. Morrell and A. V. Grosse to Universal Oil Products Company.

The catalyst recommended for dehydrogenation reactions is an oxide of Pr which may be carried by MgO or Cr_2O_3.

U.S.P. 2,161,984. Process for the Dehydrogenation of Hydrocarbons. Wm. J. Sweeney and Wm. E. Spicer to Standard Oil Development Company.

A catalyst such as formed from chromium oxide, aluminum oxide, graphite and boric acid is used. It is

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pelletted and the pills are preheated to at least 870°, avoiding however, complete fusion of the pills. Hydrocarbons such as butane are passed through an upright reaction chamber, packed with the catalyst and maintained at a temperature of about 480° to 600°.

U.S.P. 2,167,650. Treatment of Hydrocarbon Gases. A. V. Grosse to Universal Oil Products Company.

Paraffinic hydrocarbons are dehydrogenated at 400° to 770° by contacting them for a period of 0.5 to 6 seconds with a catalyst containing about 2 to 10 percent of Cr_2O_3 on a carrier of Al_2O_3.

U.S.P. 2,161,991. Process for the Production of Olefins. Hans Baehr to I. G. Farbenindustrie, A.G.

To convert normally gaseous paraffinic hydrocarbons into the corresponding olefins, they are mixed with about an equal volume of sulphur vapor and contacted at 400° to 700° with a carrier such as pumice, silica gel or coke activated by Sb, Te, Bi, etc., compounds. Oxygen may be added to the sulphur vapor. A 60 percent yield of butylene was obtained from butane.

U.S.P. 2,171,534. Catalytic Dehydrogenation of Hydrocarbons. A. V. Grosse to Universal Oil Products Company.

Into a mixture consisting of Al_2O_3 and a minor proportion of a dehydrogenating catalyst of greater activity such as Cr_2O_3 is incorporated a small amount of an alkali metal oxide in such a way that the alkali metal oxide is incorporated into the Al_2O_3 before adding to the dehydrogenation catalyst. This serves to lessen the carbon deposition.

U.S.P. 2,178,584. Diolefins. A. V. Grosse to Universal Oil Products Company.

Straight-chain monoolefins with less than 6 C-atoms are converted into diolefins by passing them under dehydrogenation conditions for a short period at a temperature of 600° and under 0.25 at. pressure over a solid catalyst consisting of a Cr, Mo or W compound on a carrier of activated alumina. Butylene gives 1,3 butadiene.

U.S.P. 2,178,601. Manufacture of Diolefins. J. C. Morrell to Universal Oil Products Company.

Mono-olefinic hydrocarbons having less than 6 C-atoms are dehydrogenated to diolefins by contacting them at temperatures from 500° to 700° C., absolute pressures of approx. 0.25 at. and for times of contact of less than 2 seconds with solid granular catalysts comprising major proportions by weight of carrying material of relatively low catalytic activity supporting minor proportions by weight of compounds of the elements in the left-hand column of group IV of the periodic table and preferably the oxides thereof. MgO, Al_2O_3, bauxite, bentonite, kieselguhr, etc., are recommended as carriers, compounds and oxides of Ti, Zr, Ce, hafnium, Th as promoters.

U.S.P. 2,178,602. Manufacture of Diolefins. J. C. Morrell and A. V. Grosse to Universal Oil Products Company.

U.S.P. 2,178,601 is extended to include the use of catalysts containing V, Cb, Ta compounds and/or their oxides.

U.S.P. 2,180,115. Process of Preparing Beta-Halogen-Butadienes-1,3. H. Lange and O. Horn to I. G. Farbenindustrie, A.G.

The beta-hylogen-butadienes, 1,3 may be obtained from 1,2-dihalogen butene without considerable formation of polymeric products by causing agents like alkali, sodium methylate, etc., which are capable of splitting off hydrogen halides to act upon a butene dihalogenated in the 1,2 positions in the presence of a boiling organic solvent having a low boiling point and eliminating from the liquid mixture the butadienes halogenated in the 2- position in the moment of their formation by means of the vapors of the solvent.

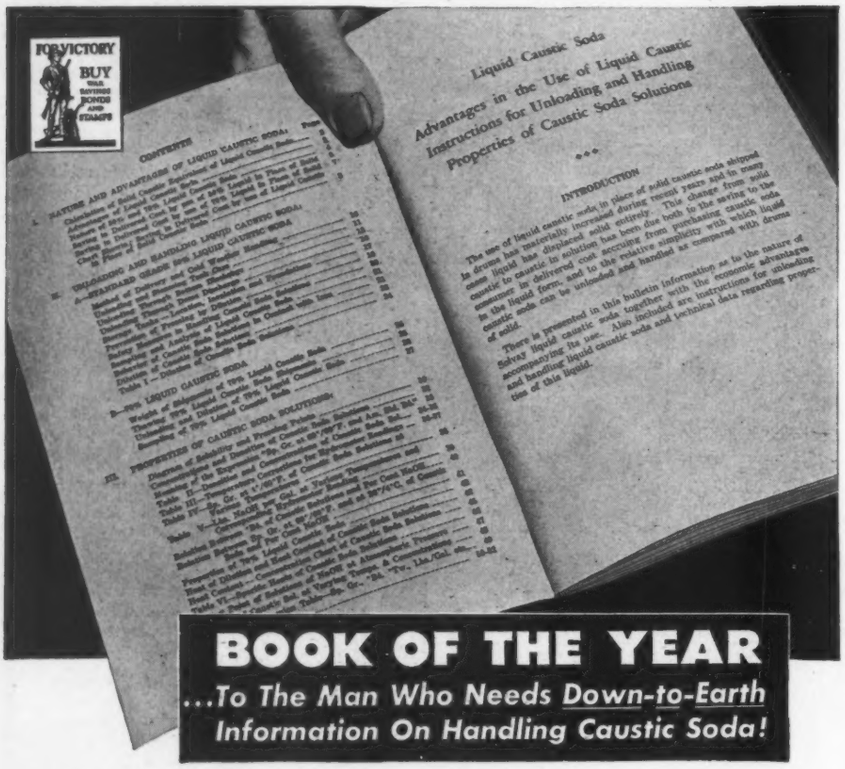
U.S.P. 2,182,431. Dehydrogenation of Organic Compounds. H. P. A. Groll and J. Burgin to Shell Development Company.

For dehydrogenation, anhydrous vapors of a hydrocarbon are contacted with a catalyst, essentially consisting of activated alumina, prepared by calcining at a temperature of 300° to 800° an aluminum hydroxide which was slowly precipitated from its aqueous solution at a temperature of about 500° to 650°.

U.S.P. 2,184,234. Dehydrogenation Process. H. P. A. Groll and J. Burgin to Shell Development Company.

A catalyst containing the oxides of Al and Cr with a preponderant proportion of Al oxide is contacted at a temperature of about 575° with a dehydrogenatable hydrocarbon. A substantial amount of hydrogen may be added in the initial phases.

U.S.P. 2,209,215. Production of Butadiene. P. J. Wiezewich and R. Rosen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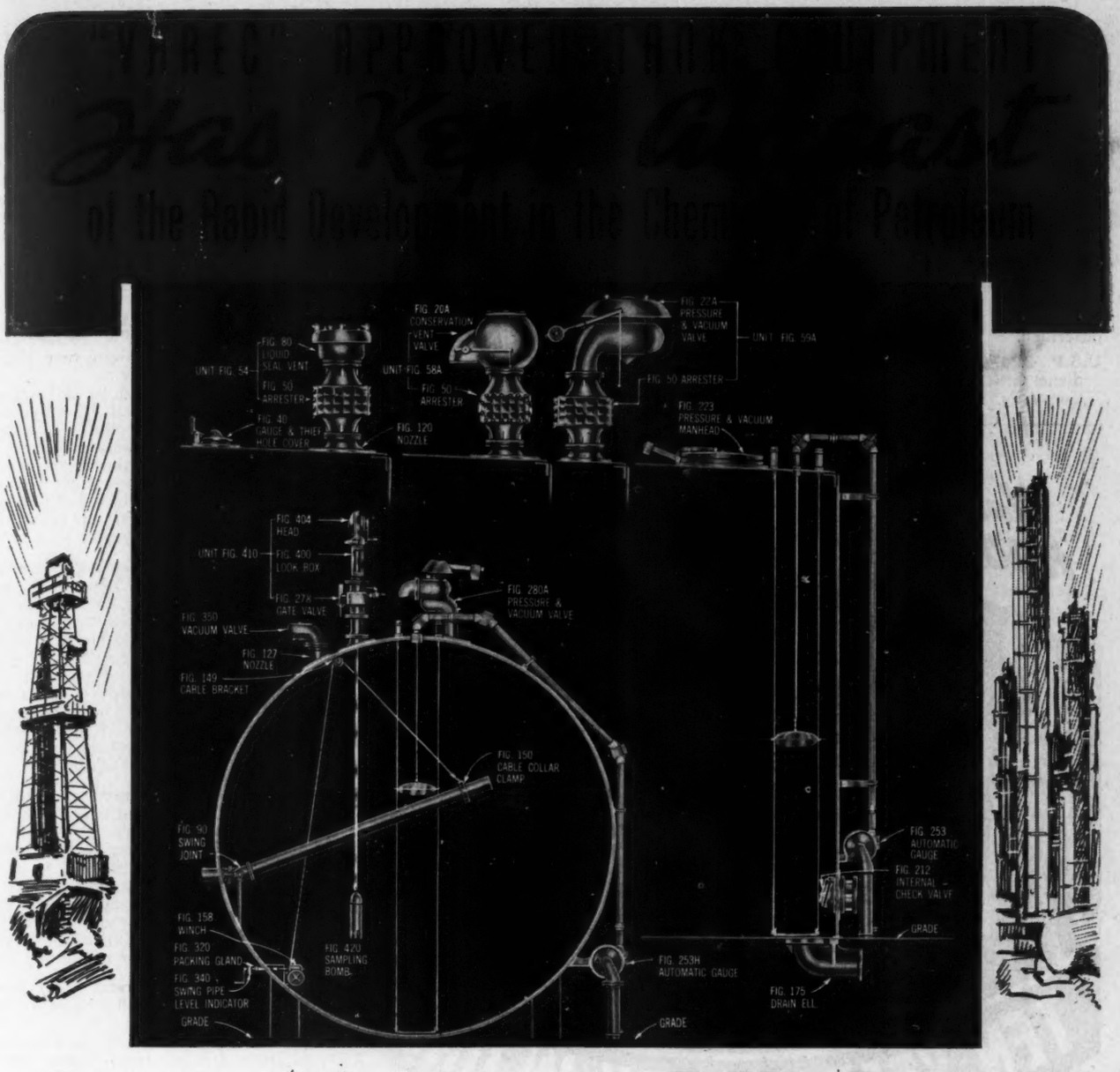

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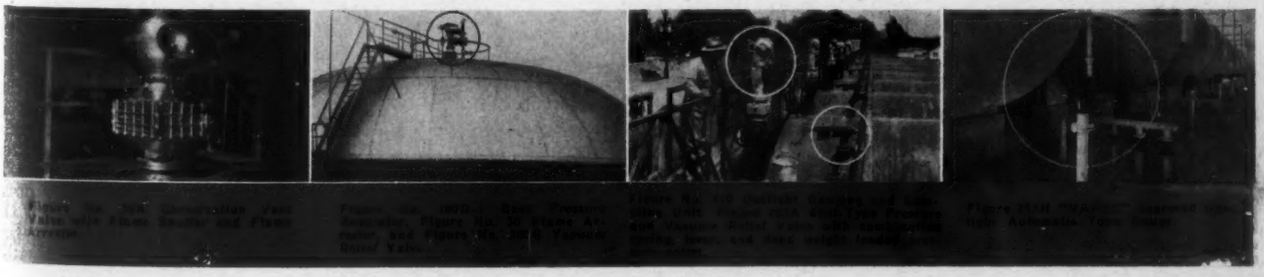

to Standard Oil Development Company.

An arrangement of apparatus is described and a process involving dehydrogenating n-butane at at least atmospheric pressure, dehydrogenating the resulting products in a second step under vacuum, removing the butadiene formed, separating fixed gases, polymerizing the butylene in the residual hydrocarbons, separating the polymers from the unpolymerized hydrocarbons, depolymerizing the polymers to butylene, recycling the butylene to the second dehydrogenating step described and recycling the unpolymerized hydrocarbons to the first dehydrogenation step described.

U.S.P. 2,207,760. Preparation of Butadiene. C. R. Russell to Dow Chemical Company.

Any dichlorinated n-butane or a mixture of such compounds is passed into a bath of molten metal chlorides comprising one or more of the chlorides of Al, K, Na, Fe, Zn, Bi, etc., at a temperature of between 400° and 600°, yielding butadiene-1,3. At reaction temperatures below 525° the yield of butadiene is improved by mixing 0.02 to 0.2 parts by weight of chlorine to the charge.

U.S.P. 2,212,043. Catalytic Dehydrogenation of Hydrocarbons. J. C. Morrell and A. V. Grosse to Universal Oil Products Company.

Aliphatic hydrocarbons are dehydrogenated by contacting them at preferably 625° for 6 seconds with a catalyst consisting of an alumina-silica carrier, supporting a minor proportion of SnO.

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U.S.P. 2,224,155. Treatment of Butane with Chlorine. C. C. Kennedy and C. R. Russell to Dow Chemical Company.

By varying reaction conditions butylene, butadiene or chloro-butane may be obtained as major product from n-butane by bringing n-butane and a catalytic proportion of Cl into contact with molten metal chlorides (an equimolecular mixture of $AlCl_3$ and KCl is especially suitable). If butadiene is the main product about at least 1.75 parts of Cl per part of n-butane are used at a temperature of 250° to 550°.

U.S.P. 2,229,652. Process for Producing Butadiene. P. Halbig, N. Platzer and A. Treibs to Consortium fuer Electrochemische Industrie.

Butadiene is produced by a process which comprises heating 1,3-butyleneglycol and an aqueous solution of a dehydration catalyst containing water in a quantity greater than the quantity of said compound to a temperature higher than 100° C. under pressure and removing the butadiene from the reaction zone as soon as it is formed.

U.S.P. 2,242,488. Converting Paraffin Hydrocarbons into Olefins. C. M. Thacker to The Pure Oil Company.

A catalyst is prepared by impregnating silical gel with a solution of copper tungstate, drying the gel, decomposing it with air at an elevated temperature and reducing the decomposed material by the action of hydrogen at an elevated temperature. Low-boiling hydrocarbons are contacted with the catalyst at 350° to 750° for dehydrogenation.

U.S.P. 2,231,446. Treatment of Hydrocarbons. A. V. Grosse to Universal Oil Products Company.

The hydrocarbon materials at a temperature of about 400° to 700° is contacted with dehydrogenating catalysts in containers whose inner surfaces, exposed to the hydrocarbons and catalysts are composed of an alloy of Al and Cu substantially free of Fe and Sn.

U.S.P. 2,257,082. Treatment of Hydrocarbons. W. A. Yarnall to The Texas Company.

Normally gaseous and low-boiling liquid hydrocarbons form olefins when brought at low pressure and at temperatures of about 350° to 600° in the vapor phase and in the presence of a substantial amount of CO into contact with a mixture of catalysts including a dehydrogenation catalyst comprising a mixture of Al and Cr oxides and a catalyst strongly promoting the interaction of CO and H, which consists of a mixture of the oxides of Mg and Th.

U.S.P. 2,259,195. Production of Dehydrogenation Products from Aliphatic Hydrocarbons and Halogenated Hydrocarbons. H. Baehr and W. Deiters to Jasco.

Numerous examples with details are given, including a process of dehydrogenating butane which consists in causing a mixture of butane with chlorine, containing at least 0.3 and at most about 2.2 mol proportions of chlorine per mol proportion butane, to react in the gas phase at temperatures between 300° and 800°, the time of heating and the temperature being so chosen as to avoid substantial formation of compounds having less C-atoms than the hydrocarbon to be dehydrogenated, quenching the gaseous reaction mixture

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to about ordinary temperature by bringing it into contact with partially chlorinated aliphatic hydrocarbons containing four C-atoms, removing HCl by bringing the gaseous reaction mixture into contact with a solvent for HCl, and separating the unsaturated hydrocarbons obtained from co-present material.

U.S.P. 2,265,641. Production of Butadiene by the Dehydrogenation of Butene. O. Grosskinsky and G. Hoffmann to Jasco, Inc.

Butane is mixed with steam and the gaseous mixture is contacted at 500° to 700° with a catalyst consisting of over 50 percent ZnO and also containing at least one oxide of Cr, V, Mo, U, or W.

U.S.P. 2,274,358. Production of Butadiene. A. Cantzler and H. Krekeler to Jasco, Inc.

Butene is heated to about 500° (suitably 625° to 650°) with at least an equal weight of HCl.

U.S.P. 2,275,135. Butadiene Extraction. E. V. Fasce to Standard Oil Development Company.

Diolefins are recovered from hydrocarbon mixtures containing the same by contacting the mixture with a clear solution of a cuprous salt and a water-soluble organic nitrile (preferably acetonitrile) together with a solvent such as water or ethylene glycol, etc. The preferred cuprous chloride forms definite compounds with organic nitriles. After the solution is saturated at about 50° F., it is heated to 160° F., expelling the absorbed gas which is rich in diolefins. The diolefins can be purified by several repetitions of the process.

Polymerization of Butadiene And of Styrene

U.S.P. 1,938,730. Rubber-Like Mass Containing Styrol Polymerizates. Eduard Tschunkur and Walter Bock to I. G. Farbenindustrie Aktiengesellschaft.

Mixtures of butadiene and polymerizable styrol compounds (styrol, alpha-alkyl styrols, nuclear homologues of styrol, polyvinyl benzenes, etc.) are polymerized in emulsion at temperatures between about 40° to about 80° C.

U.S.P. 1,938,731. Rubber-Like Mass Containing Styrene Polymerizates. Eduard Tschunkur and Walter Bock to I. G. Farbenindustrie Aktiengesellschaft.

Butadiene hydrocarbons and olefin benzene substances (styrene, alpha-alkyl styrenes, polyvinyl benzenes and nuclear homologues of these compounds, etc.) are polymerized together in emulsion at temperatures between about 40° to about 80° C.

U.S.P. 1,973,000. Rubber-Like Masses from Butadiene Hydrocarbons and Polymerizable Nitriles. Erich Konrad and Eduard Tschunkur to I. G. Farbenindustrie Aktiengesellschaft.

A mixture of at least 60 percent of a butadiene hydrocarbon of the formula

$$H_2C = C - C = CH_2$$
$$\quad\quad\; |\quad\quad |$$
$$\quad\quad\; X\quad\; H$$

where X means hydrogen or methyl, and at least 40 percent of the compound of the formula

$$H_2C = C - C \equiv N$$
$$\quad\quad\; |$$
$$\quad\quad\; R$$

where R means hydrogen or methyl, is polymerized in emulsion at temperatures from about 30° to about 100° C.

U.S.P. 2,066,329. Chemical Products and Processes for Producing Same. Wallace H. Carothers, Arnold M. Collins and James E. Kirby to E. I. du Pont de Nemours & Company.

Halogen-2-butadiene-1,3, especially chloro-2-butadiene, is polymerized in the presence of other polymerizable compounds of the lower members of the various series of the butadienes. The properties of the resulting product can be varied by changing the conditions of the polymerization, i.e., changing the proportions of the various butadienes added, varying the time, temperature, pressure, the presence or absence of catalysts, inhibitors, solvents, emulsifying agents, etc.

U.S.P. 2,066,330. Chemical Products and Processes for Producing Same. Wallace H. Carothers, Arnold M. Collins and James E. Kirby to E. I. du Pont de Nemours & Company.

Haloprenes are polymerized in the presence of a vinyl compound of the class consisting of vinyl ethers, vinyl esters, vinyl carbinol, esters of vinyl carbinol, vinyl acetylenes, vinyl aromatic hydrocarbons and vinyl aromatic compounds consisting of carbon, hydrogen, halogen and alkoxy groups, the halogen and alkoxy groups being present as substituents on a carbon atom of

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an aromatic ring. The mixture may be polymerized in the presence or absence of light, heat, air or oxygen, inert solvents, diluents, catalysts, or inhibitors. Pressures of less than 1 atmosphere to 6000 atmospheres may be used.

U.S.P. 2,066,331. Chemical Products and Processes for Producing Same. Wallace H. Carothers, Arnold M. Collins and James E. Kirby to E. I. du Pont de Nemours & Company.

Modified interpolymers of halogen-2-butadiene-1,3 are obtained by polymerizing a haloprene in the presence of a polymerizable compound containing an activated carbon-carbon double bond; such compounds belong to the class consisting of alpha, beta- unsaturated aldehydes, ketones, acids, their esters, anhydrides, and nitriles. Examples and conditions are given for the preferred haloprene chloro-2-butadiene-1,3.

U.S.P. 2,067,304. Manufacture of Artificial Rubber-Like Masses. Eduard Tschunkur and Walter Bock to I. G. Farbenindustrie Aktiengesellschaft.

Butadiene-1,3 and alkyl substituted butadienes are polymerized in the presence of emulsifying agents, such as the salts of fatty acids, salts of sulfo fatty acids, alkali metal salts of alkyl-substituted aromatic sulfonic acids and salts of high-molecular bases with inorganic and organic acids, and in the presence of water (up to about 10 percent by weight) in an amount insufficient for complete solution of the emulsifying agent.

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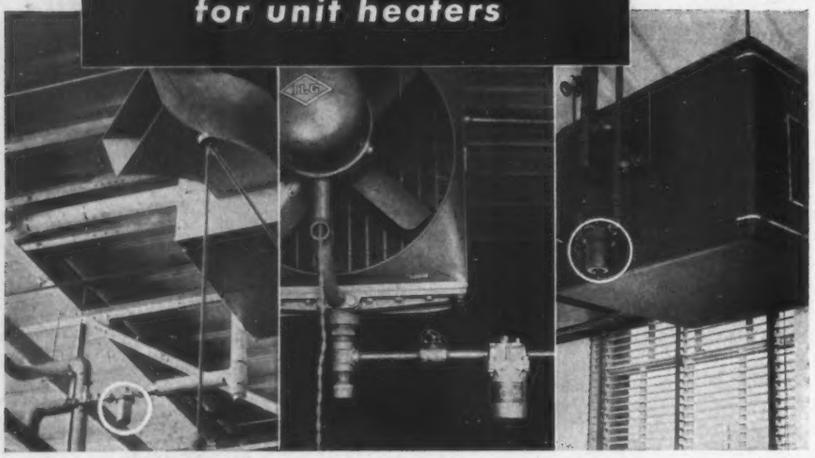

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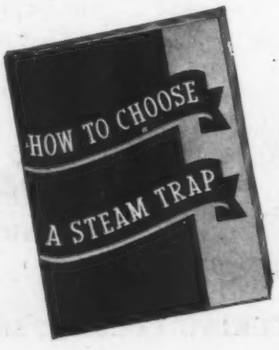

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U.S.P. 2,119,629. Caoutchouc-Like Products and a Process of Preparing Them. Ludwig von Zütphen to I. G. Farbenindustrie Aktiengesellschaft.

Caoutchouc-like products are obtained by subjecting to polymerization the compound produced by the addition of hydrochloric acid to vinyl-butadienyl-acetylene.

U.S.P. 2,137,393. Process of Polymerizing Styrene. George L. Dorough and George D. Graves to E. I. du Pont de Nemours & Company.

Monomeric styrene or a mixture of monomeric styrene with an ester of methacrylic acid is polymerized in aqueous dispersion in the presence of sulfur dioxide as a catalyst.

U.S.P. 2,151,382. Diolefin Polymerization Process. Jesse Harmon to E. I. du Pont de Nemours & Company.

Olefins, or diolefins, or halogen substitution products thereof, or mixtures thereof, are polymerized at temperatures from 0° to 50° C. with hydrated boron fluoride having from one to two mols of water per mol of BF_3. Boron fluoride is removed from the product by washing with water or dilute alkali.

U.S.P. 2,161,038. Manufacture of Rubber-Like Polymerization Products. Bernard James Habgood and Leslie Budworth Morgan, to Imperial Chemical Industries, Limited.

Butadiene is interpolymerized in aqueous emulsion with not more than half its weight of methacrylic ester of the formula

$$CH_2=C(CH_3)-C(=O)-O-CH_2CH_2O-R$$

wherein R stands for either an alkyl radical containing not more than 4 carbon atoms, or a phenyl, tolyl or xylyl radical. Emulsifying agents are salts of bases of high molecular weight and organic or inorganic acids (diethylaminoethyloleylamide acetate or hydrochloride, etc.). Usual catalysts may be employed, such as hydrogen peroxide, etc.

U.S.P. 2,180,082. Polymerization Products from Butadiene or Its Substitution Products and Solid Polymerized Isobutylene. Martin Mueller-Cunradi and Walter Daniel to I. G. Farbenindustrie Aktiengesellschaft.

Rubber-like polymerization products are obtained by polymerizing butadiene or its substitution products (isoprene, dimethylbutadiene, phenylbutadiene or chlorobutadiene) in the presence of solid highly polymerized isobutylene by known methods, as for example with sodium, by simple heating or in aqueous emulsion in the presence of peroxides.

U.S.P. 2,181,771. Method of Polymerization of Styrene. Norman D. Scott to E. I. du Pont de Nemours & Company.

Styrene is polymerized in the presence of about 1 to 10 percent of an addition compound made from an alkali metal and a polycyclic aromatic hydrocarbon, such as the sodium addition compound of naphthalene ($C_{10}H_{18}Na_2$). Temperatures as low as —60° F. or as high as 50° to 60° F. may be used.

U.S.P. 2,194,416. Polymerization Product. Walter Bock to I. G. Farbenindustrie Aktiengesellschaft.

1-furylbutadienes-1,3, i.e., compounds having a butadiene radical attached to furane in α-position, are polymerized in

aqueous emulsion in the presence of oxygen or oxygen-yielding substances (potassium persulfate, hydrogen peroxide, and the like) and compounds exerting a regulating effect (dialkyl xanthogen disulfides).

U.S.P. 2,200,705. Interpolymerization Products of Butadiene and a Vinyl Ethinyl Carbinol. Wilhelm Sandhass, Walter Daniel and Kornelius Mühlhausen to I. G. Farbenindustrie Aktiengesellschaft.

Interpolymerization products are formed by polymerizing in aqueous emulsion in the presence of peroxides a mixture of butadiene and a vinyl ethinyl carbinol (vinyl ethinyl carbinol, 1-vinyl-ethinyl-cyclohexane-1-ol).

U.S.P. 2, 205, 239. Process for Preparing Cyano-2-Butadiene-1, 3. Albert S. Carter and Frank W. Johnson to E. I. du Pont de Nemours & Company.

Rubber-like polymers are prepared from a mixture of chloro-2-butadiene-1, 3 and cyano-2-butadiene-1, 3. The cyano-2-butadiene-1, 3 is prepared by acylating α-vinyl lactic nitrile.

U.S.P. 2,209,746. Process of Polymerizing Butadienes. Georg Ebert and Philipp Orth to Jasco, Incorporated.

Butadienes and other polymerizable compounds are polymerized industrially with alkali metal in tubes containing conveyor worms in which the material to be polymerized is moved forward during the polymerization and the product is withdrawn at the end.

U.S.P. 2,211,032. Polymerization of Butadienes. Rudolf Seidler and Wilhelm Pannwitz to Jasco, Incorporated.

Butadienes or a mixture of butadienes with other organic compounds which have a carbon double linkage (acrylic nitrile, styrene, vinyl methyl ketone or fumaric acid ester) are polymerized in aqueous emulsion at about 50° C. in the presence of catalytic amounts (less than 1 percent by weight) of organic bases containing nitro groups and an open-chain double linkage between two carbon atoms (5-nitro-2-styrlbenzimidazol) or between a carbon atom and a nitrogen atom in the molecule (benzal-p-nitraniline, p-nitro-benzal-p-nitraniline, etc.).

U.S.P. 2,215,379. Preparation of Copolymers of Butadiene and Vinylidene Chloride. Lorin B. Sebrell to Wingfoot Corporation.

Butadiene and its homologues are polymerized in emulsion at about 50° C. in the presence of catalysts (benzoyl peroxide, sodium perborate, etc.) or promotors (carbon tetrachloride, trichloro-propionitrile) with vinylidene chloride in which the butadiene is present in amount from 50 to 65 percent of the total monomer treated.

U.S.P. 2,216,958. Manufacture of Artificial Rubber by the Polymerization of Butadienes. Wilhelm Pannwitz and Bernhard Ritzenthaler to Jasco, Incorporated.

The time of polymerization of butadiene, its homologues, its halogen substitution products, or the inter-polymerization with other substances may be shortened by the use of an emulsifying agent salts of compounds of the general formula

$$X\text{-}CH_2\text{-}CH_2\text{-}Y\text{-}CH_2\text{-}CH_2\text{-}NZ$$

wherein Y means oxygen or sulfur, NZ means the radical of a secondary amine or a quaternary ammonium compound, X means the radical of a secondary amine, an acid amide, an ester, an ether, a quaternary ammonium compound or a hydroxyl group at least one of the radicals X and Z containing at least 8 carbon atoms being directly attached to each other in an open chain linkage.

U.S.P. 2,218,362. Rubber-Like Interpolymers of Butadiene and Methyl Methacrylate and Process for Making Same. Howard W. Starkweather and Arnold M. Collins, to E. I. du Pont de Nemours & Company.

Butadiene is polymerized at temperatures from about 20° to about 100° C. in aqueous emulsion and in the presence of catalysts (hydrogen peroxide, etc.) with the methyl ester of alpha methyl acrylic acid (also called methyl methacrylate) in which about 15 percent to about 50 percent of the two polymerizable materials is methyl methacrylate. Emulsifying agents containing substituted ammonium or sulfonium salts of long-chain (12 or more carbon atoms) hydrocarbons are suited, such as, oleoamidoethyl-dimethylamine hydrochloride, cetyl trimethyl ammonium bromide.

U.S.P. 2,222,967. Preparation of Synthetic Rubber-Like Materials. Heinz Wollthan and Wilhelm Becker to Jasco, Incorporated.

At a pH of below 7 butadiene or admixtures of butadiene with other polymerizable compounds are polymerized in aqueous emulsion employing as emulsifying agents water-soluble products

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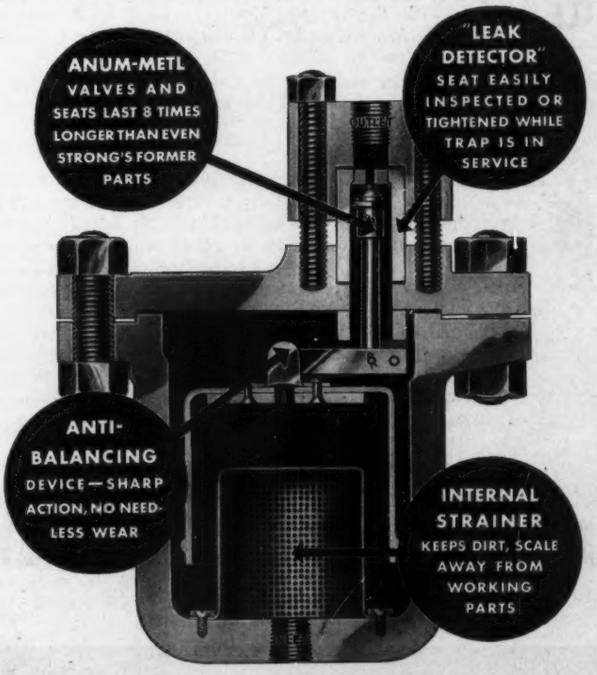
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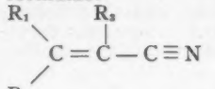
of the interaction of compounds containing an ethylene oxide linkage with water-insoluble organic hydroxy compounds containing a higher aliphatic radical. Required pH value can be reached by the addition of free acid such as acetic acid, etc. Usual catalysts can be employed.

U.S.P. 2,224,837. Polymeric Product of Aromatic Hydrocarbons Substituted by the $CH_2=CH-$ Radical. Leo Rosenthal and Helmuth Meis to I. G. Farbenindustrie Aktiengesellschaft.

Polymeric products are obtained by causing an acid-reacting polymerization catalyst (borofluoracetic acid) which is capable of polymerizing styrene to react at elevated temperatures upon a mixture in an indifferent solvent (benzene) of an aromatic hydrocarbon substituted by the radical $CH_2=CH-$ and at least one aromatic oxygen containg compound selected from the group consisting of aromatic hydroxy compounds (phenol) and ethers of aromatic hydroxy compounds (anisol), the aromatic hydrocarbon substituted by the radical $CH_2=CH-$ being present in the ratio of from 0.5 to 16.3 mols per mol of aromatic oxygen containing compound. Numerous examples are given.

U.S.P. 2,227,900. Manufacture of Rubber Articles. Bernard James Habgood and Leslie Budworth Morgan to Imperial Chemical Industries Limited.

Vulcanized natural rubber is bonded to vulcanized synthetic rubber made by the interpolymerization of a mixture of butadienes and/or its homologues with nitriles, ketones and esters derived from acrylic acid and having the following formulae:



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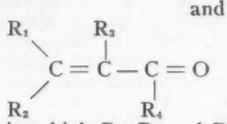

in which R_1, R_2 and R_3 stand for hydrogen or alkyl, and R_4 stands for alkyl or alkoxy.

U.S.P. 2,230,894. Synthetic Rubber-Like Material. Walter Gumlich, to Jasco Incorporated.

Butadiene polymers prepared by polymerizing in an aqueous emulsion are subject to an oxidizing treatment by means of oxygen, such as, by passing a stream of air through the mixture, in the presence of antioxidants and of hydrazines prepared from the mono-substituted hydrazines.

U.S.P. 2,231,623. Synthetic Rubber-Like Materials. Bernard James Habgood, Elias Isaacs, and Leslie Budworth Morgan, to Imperial Chemical Industries, Limited.

Butadiene-1,3 or its methyl homologues is polymerized in aqueous emulsion with acrylates, especially the methyl or ethyl esters of beta-(2-furyl) acrylic acid.

U.S.P. 2,234,076. Emulsion Polymerization of Butadienes. Walter Gumlich and Ingofroh Dennstedt, to Jasco, Incorporated.

Increased yields of polymers from butadiene and mixtures of other polymerizable substances are obtained by polymerization in emulsion in the presence of a catalyst composed of the various complex compounds of iron, such as, haemin, iron containing phthalocyanines, alkali metal salts of iron complexes of arabonic acid, pyrogallol or gallic acid.

U.S.P. 2,234,215. Plastic Polymeric Derivatives of Chloroprene and Process of Producing the same. Mortimer A. Youker, to E. I. du Pont de Nemours & Company.

Chloroprene is polymerized in presence of sulphur at temperatures between 0° C. and 100° C. Polymerization in emulsion may be accelerated by increasing the temperature, adjusting the pH, by proper choice of the emulsifying agent, or by the use of a catalyst containing the peroxide nucleus. The polymer is plasticized without extensive milling by the addition of one or more of the compounds of the general formula R-S-R_1, where R is an alkyl, aryl, thiazyl, thiocarbamyl, xanthogenyl, thioxanthogenyl, aromatic acyl or aromatic thioacyl group and R_1 is hydrogen, a base-forming radical, or a group represented by -S_n-R, in which n is a whole number less than 4 and R is one of the groups represented by R above. Invention is illustrated by many examples.

U.S.P. 2,248,107. Polymerization of butadiene. Kurt Meisenburg, Ingofroh Dennstedt, and Ewald Zaucker, to Jasco, Incorporated.

Butadiene is polymerized in emulsion in the presence of organic sulphur containing compounds which are soluble in the monomeric substance to be poly-

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merized and such sulphur compounds contain at least 2 sulphur atoms directly connected with each other (i.e., organic disulfides). These sulfides may be selected from the group consisting of dialkylxanthogendisulfides, di(benzoic acid ester)-tetrasulfides, tolydisulfide and tolytrisulfide.

U.S.P. 2,256,148. Method of Preparing Copolymers. Joy G. Lichty, to Wingfoot Corporation.

Mixtures of polymerizable substances, i.e., butadienes, esters and nitriles of acrylic acids, or vinyl compounds are polymerized to give improved yields in presence of 3 to 6 percent of a chloropropionitrile.

U.S.P. 2,260,475. Preparation of Synthetic Rubber-Like Materials. Hans Murke, to Jasco, Incorporated.

Butadiene-1,3 is subjected to copolymerization in aqueous emulsion with other polymerizable compounds in the presence of a tertiary amine which is soluble in at least one of the polymerizable compounds. Tertiary amines act as stabilizers for the monomeric products against polymerization and also protect the polymeric products against cyclization.

U.S.P. 2,264,191. Stabilized Dispersions of Chloroprene Polymers and Process of Processing Same. Howard W. Starkweather, and Frank N. Wilder, to E. I. du Pont de Nemours & Company.

Stable aqueous dispersions of polymers are obtained by polymerizing chloroprene in aqueous emulsion in the presence of sulphur from about 0.25 percent by weight up to about the amount soluble in the chloroprene under the conditions of the polymerization.

U.S.P. 2,264,811. Polymerization of Conjugated Diolefinic Hydrocarbons to Drying Polymers. Henry S. Rothrock, to E. I. du Pont de Nemours & Company.

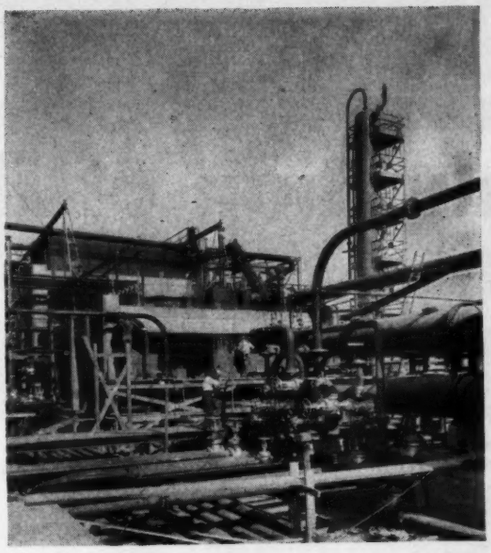
Aliphatic open-chain conjugated diolefinic hydrocarbons, particularly butadiene and its homologues, in an inert solvent (benzene, etc.) are polymerized under pressure at 100° to 170° C. in the presence of from 4 percent to about 14 percent by weight of alkali metals, the alkali metal hydrides, and the alkaline earth metals.

U.S.P. 2,266,794. Rubber-Like Interpolymers of Butadiene Hydrocarbons and Fumaric Acid Esters and Process of Producing the Same. Wilhelm Pannwitz, Bernard Ritzenthaler, Heinrich Hopff and Gustav Steinbrunn, to I. G. Farbenindustrie Aktiengesellschaft.

Aqueous emulsion mixtures of butadiene, or butadiene with other polymerizable compounds, are interpolymerized with ethylene α-β-dicarboxylic acid ester, such as fumaric or maleic acid esters in the presence of polymerization catalysts (potassium persulphate, hydrogen peroxide, etc.) and at temperatures between the ordinary temperature and about 80° C.

U.S.P. 2,273,158. Polymerization Process. Robert M. Thomas and Donald C. Field, to Standard Oil Development Company.

Isoolefinic (isobutylene) and diolefinic (butadiene) compounds are interpolymerized at temperatures between —50° and —150° C. and in the presence of a Friedel-Crafts type catalyst (aluminum chloride, boron trifluoride, stannic chloride, titanium tetrachloride, zirconium chloride, etc.).



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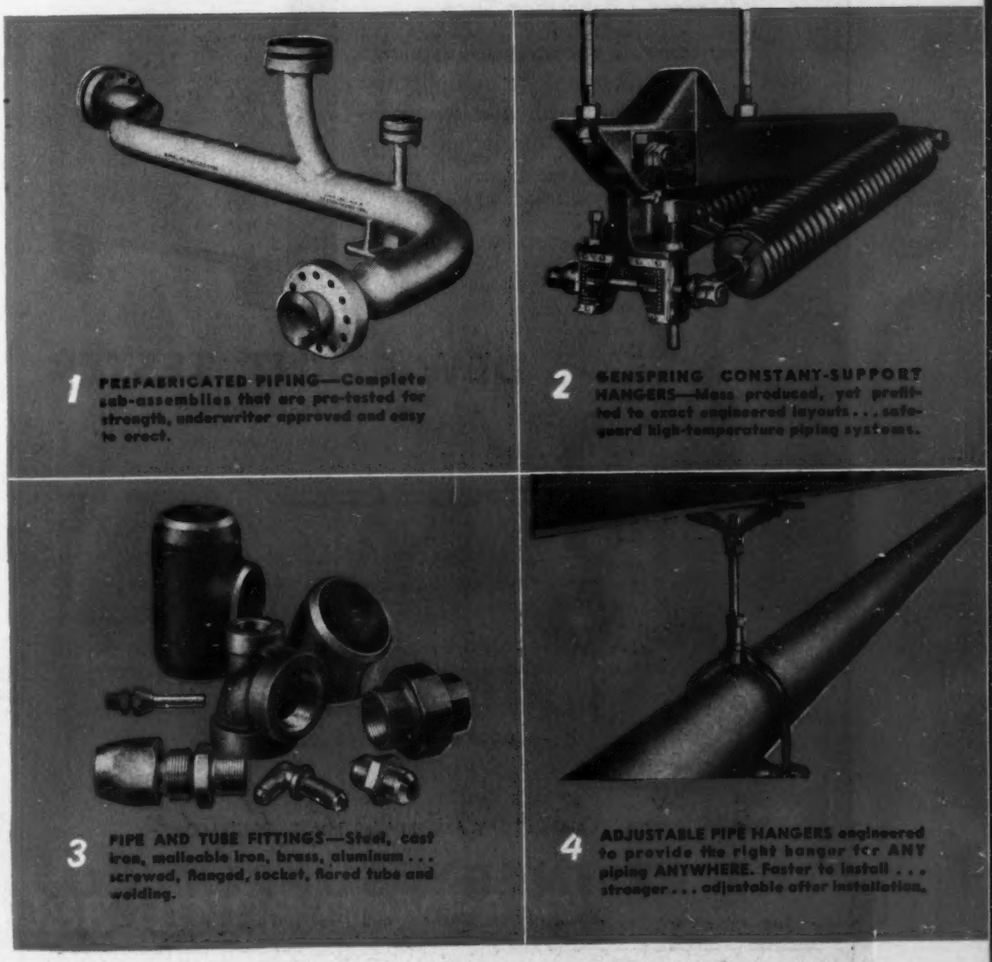

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The Evaluation of Research*

EUGENE AYRES
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IT IS a curious circumstance that research, which is the most scientific of all pursuits, should be one of the most difficult to evaluate in dollars. Those of us who are enthusiastic about research are apt to refer to its value in most general terms. We say it is valuable because of this and because of that—all abstract qualities—much as we would define the value of honesty as a business asset.

Lord Kelvin is often quoted as saying that "when you can measure what you are speaking about and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely, in your thoughts, advanced to the stage of science, whatever the matter may be." Perhaps Lord Kelvin would say that despite the eminently scientific nature of research, its appraisal for business purposes is only dimly understood.

It is natural that no generalizations can be made concerning the monetary value of research carried out by an individual. There are notorious cases of extraordinary returns from very little research, and other more familiar cases in which research has continued year after year without tangible return. But in organized industrial research, the element of chance is less important for several obvious reasons, among which are the number and variety of technical viewpoints and, particularly, the character of the research problems. In general, there are two kinds of research problems. On the one hand there are problems that are fruitful only if we are fortunate enough or clever enough to get a particular kind of answer, and on the other hand, there are research problems which are fruitful without regard to the answer.

Costs of Research Work

Suppose we have reason to believe that a certain organic compound might have useful properties as an antioxidant. We do a lot of work to find out how to prepare this organic compound and then we test it to see if it has the desired antioxidant quality. If the answer is "yes," we may balance the cost of research work on this problem against the value of the antioxidant, but if the answer is "no," we may have no economic justification for this research expense. Here the value of the research depends upon the kind of result obtained. But suppose we undertake to determine the optimum conditions for a process in order that we may know how to design a commercial plant. Here the result has the same value regardless of the conditions which are found to be optimum. A considerable proportion of industrial research is concerned with this second type of problem, and from the voluminous experience of research laboratories in many industries, certain numerical criteria are beginning to emerge.

It is probable that no two research laboratories would agree in detail on the average relationship between the different elements of cost of develop-

*Before the Division of Industrial and Engineering Chemistry, American Chemical Society, Buffalo, September 8, 1942.

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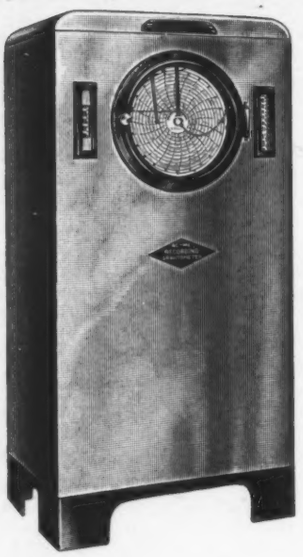

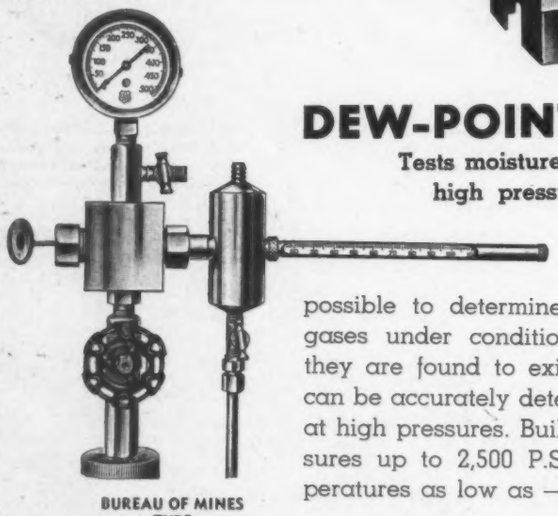

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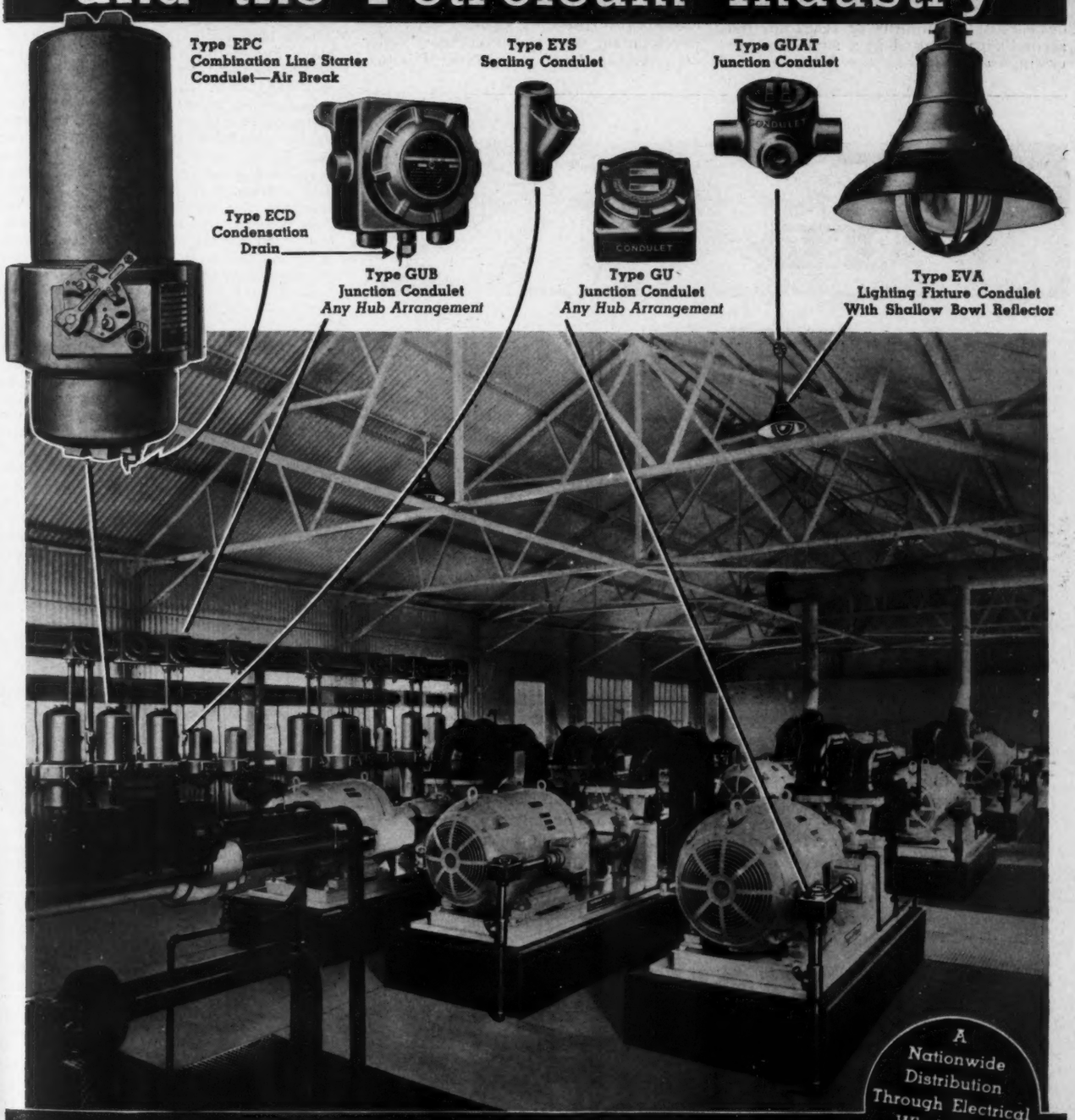

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ment, but they probably would not be very far apart. These cost relationships have been formulated by economic studies of many different sorts. For example, a company found it necessary to go into the manufacture of a new chemical in a hurry. There were no large-scale precedents for this operation but two good process ideas were offered by the research department. Because of the emergency, it was decided to commercialize one idea without any research, while the second idea was carried in orderly fashion through laboratory and pilot plant. Despite the delay occasioned by months of research, the second idea resulted in a smoothly operating plant before the first and at much lower development cost. The first idea was then sent back to the research laboratory and a year later superseded the second.

In another case, a new process was commercialized from laboratory data without pilot plant research. A few years later a new plant of the same size was designed and built from data secured from the first plant.

From these and dozens of other cases, it is possible to come to some general numerical conclusions which, being averages, apply to no specific case with any accuracy, but which may apportion development cost in the correct "order of magnitude" for a majority of industries and companies. Here are three generalized cases:

	Units of Cost		
1. Laboratory research..	1	1	0
2. Patent prosecution ..	1	1	0
3. Pilot-plant research...	5	0	0
4. Excess design and construction	5	15	20
5. Getting process in operation	25	50	65
Total development cost	37	67	85

"Getting Process in Operation" is the part of development cost that comes after the commercial plant is built. There are some companies which always figure this cost because it is the largest element of development expense and because it affords one of the best measures of technical management. But some other companies permit this cost to be absorbed in operating expense and do not worry about it. This cost may be figured in many different ways but perhaps most conveniently by subtracting the operating profit for the first year of operation from the operating profit for the second year of operation; making indicated adjustments for proper comparison and including, of course, such items as structural changes and losses of materials.

Apportioning Costs

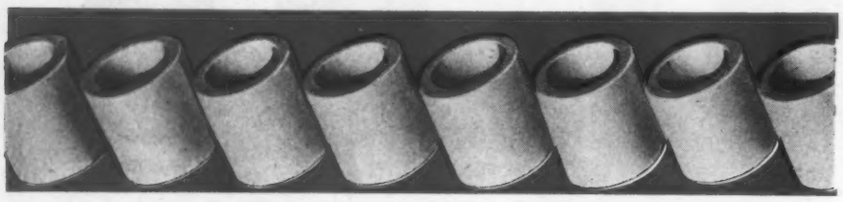
"Excess design and construction" cannot be figured so easily, but can be estimated by competent engineers. Total design and construction cost cannot be regarded as development expense because thoroughly commercialized plants also must be designed and built. But, because of technical uncertainties, it always costs more to design and to build a new process than an old one, and the difference is development expense. The more we know about a process before we start to build, the smaller this difference and also the smaller the cost of getting the plant into operation.

Every authorization for plant construction covers not only investment but also a proportion for development expense; but this proportion cannot be ear-marked as such for the very good reason that it cannot be predicted in advance.

The first column expresses the relationship between cost elements which perhaps may be regarded as ideal and, therefore, as showing a minimum total for the average research project. Laboratory research and patent prosecution are indicated as of the same order of magnitude. Pilot-plant expense is five times as high as laboratory expense. "Excess design and construction" is made equal to pilot-plant expense because experience indicates that this is about as low as competent research can bring it and "Getting process in operation" is five times as great for the same reason.

The most significant comparison is between the columns. Without any research, the total development cost is about 2.3 times the total cost with adequate research. Laboratory research without pilot-plant work figures 1.8 times the ideal.

It is interesting to apply these ratios to special cases. For example, a chemical company, during a certain period, spent on the average about $3,000,000 per year for process development. During that period this company did no laboratory or pilot-plant research on these processes. The $3,000,000 was



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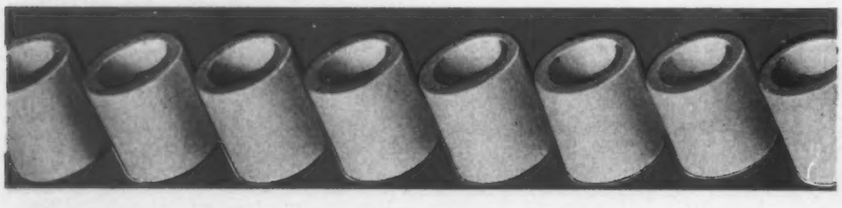

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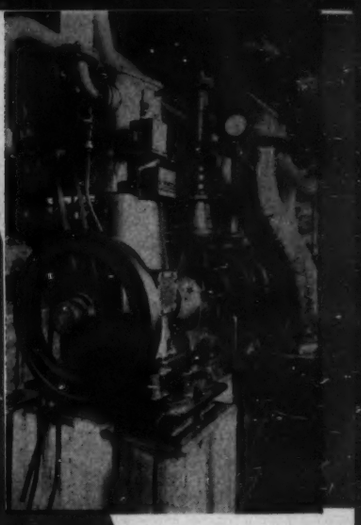
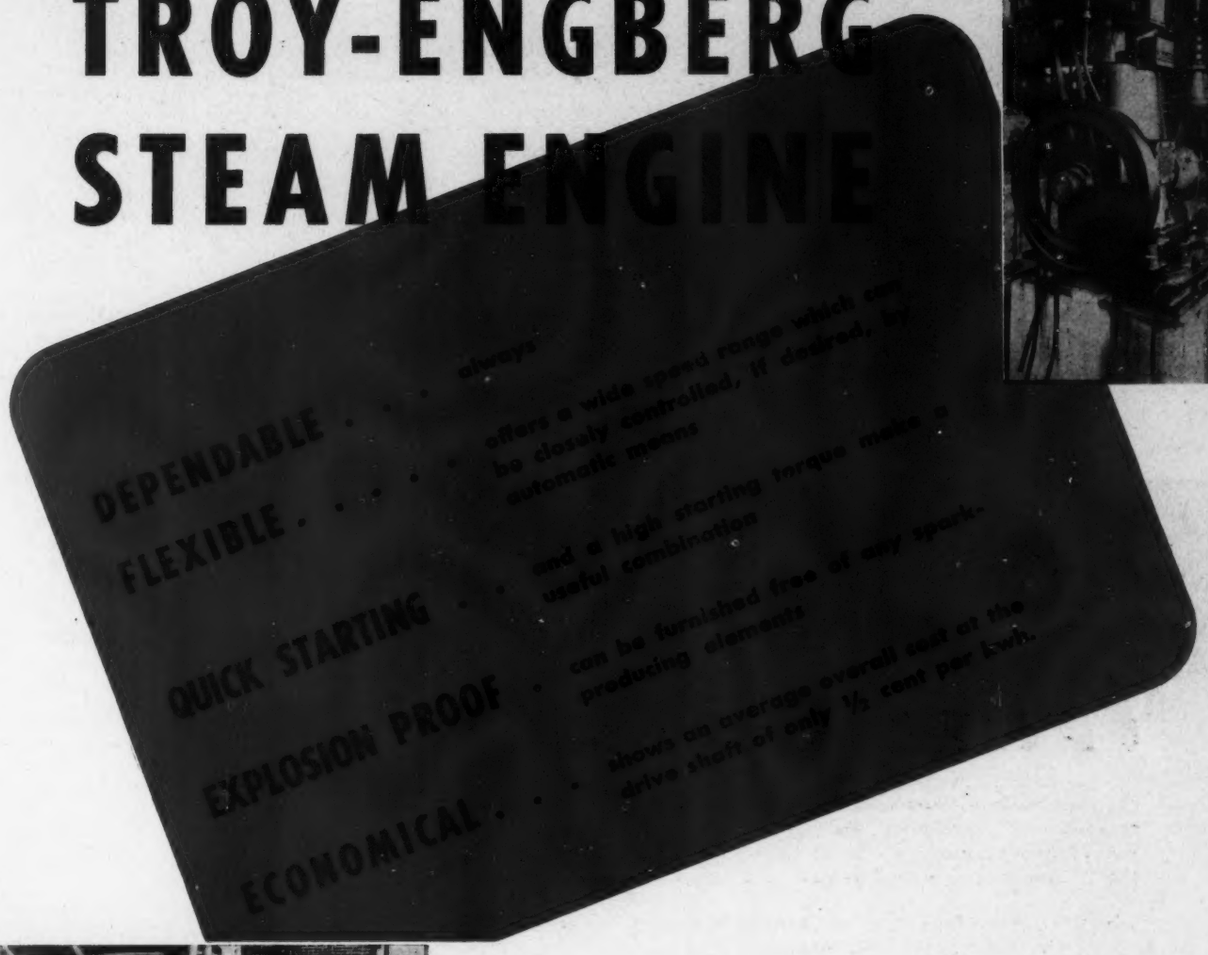
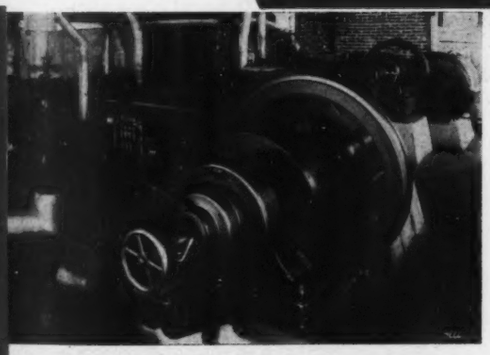
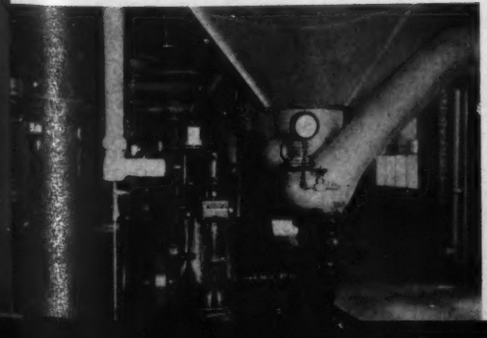



DEPENDABLE . . . . always
FLEXIBLE . . . . . offers a wide speed range which can be closely controlled, if desired, by automatic means
QUICK STARTING . . . and a high starting torque make a useful combination
EXPLOSION PROOF . . can be furnished free of any spark-producing elements
ECONOMICAL . . . shows an average overall cost at the drive shaft of only ½ cent per b.h.p.





Considering these advantages it is not difficult to understand why so many Troy-Engberg Steam Engines can be found in refineries, driving various equipment but particularly charging and transfer pumps. They are reliable drives, staying on the job month after month. They are so simply and so well constructed as to serve for years without the need of major repairs; seldom any minor ones.

Dependability must come first in refinery equipment but with the Troy-Engberg Steam Engine other desirable advantages are obtained, too. It's the ideal drive for the refinery for such equipment as pumps, compressors, fans, blowers and generators.

TROY ENGINE & MACHINE CO.

Established 1870

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made up of "excess design and construction" and "getting process in operation." according to the table, if this company had done $175,000 of pilot-plant work per annum, it could have reduced the total development expense for these processes from $3,000,000 to $1,300,000 per annum. This would have meant a saving of $1,700,000, or nearly 1000 percent profit from research investment.

This conclusion may well be absurd. The table can be very wrong in specific cases but, on the other hand, it can be wrong in either direction. The conclusion may well be correct.

Regardless of accuracy of application, the generalized figures point toward some interesting conclusions:

1. Patent prosecution and laboratory research are almost negligible portions of total development expense.
2. Total research, including adequate pilot-plant work under the most favorable conditions, figures around one fifth of total development expense.
3. The minimum development expense is associated with adequate research expenditures.
4. Research is about the most profitable investment that can be made.

The question is sometimes raised—Can we avoid development expense by the installation of processes developed by others? The answer to this question is clear. We can avoid the small parts of development expense, but we usually cannot avoid the large ones. Many cases can be pointed out in which a company has had lower development expense on processes purchased from others, but there are many other cases in which the development expense has been actually greater. Unless a process has already been thoroughly commercialized, whether a purchased process costs more or less than an independently developed process depends primarily upon the quality of the pilot-plant work. Certain purchased processes have cost a chemical company far more for development than as though they had passed through the company's own laboratory and pilot plant because the preliminary work that had been done by others failed to provide sufficient data for economical design and construction. In general, the only cases in which we can avoid the major part of the normal development expense of new processes are those in which processes have been operated for a sufficint time to iron out all the kinks. But in such cases processes are likely to become obsolete about the time we get them into operation.

Technical Obsolescence

Technical obsolescence must be regarded as of the utmost importance in the present argument. If we pay a million dollars as paid-up royalties for a certain process, this may not seem to be a serious expense if we can assume that this process will not become obsolete. But this is frequently not the case. By the time we get this process in operation, it will be somewhat obsolete, and by the time we install its successor and get it into operation this also is likely to be obsolete. Paid-up royalties cannot be regarded as non-recurring expenses because technical obsolescence sees to it that such expenses recur with dismal regularity.

It appears that process research should be justified (1) by its saving of many times its cost by the reduction of the other greater development costs, and (2) by its effect upon the vital element of timing. Either one of these reasons is sufficient in itself and it is unnecessary to include the reason that research may enable us to charge royalties or to be immune from paying royalties. This last factor has to do not with the justification of research, but rather with the jusification of patent prosecution. There is no reason to compare the cost of research with the cost of royalties. The comparison should be made between the cost of patent prosecution and the amount of royalties received plus the amount of royalties which otherwise we would have to pay.

Royalties are normally set as high as the traffic will bear. The only reason royalties in general in the chemical industries are moderate is because competitive research has prevented any company from securing a monopoly on any important process. This makes the royalties themselves competitive and the company with the strongest patent position will either receive royalties or, if it does not wish to follow the necessary procedure for securing licensees, it will at least pay the minimum royalties. The royalties never seem very large when they are figured on a unit of material, but our competitive disadvantage is measured not by the amount of royalties, but by double this amount, for while we are paying the royalties, the other company is receiving them.

The royalties paid by companies who

THE DURAMETALLIC TWIST

1. Processed to retain lubrication.
2. Provides readier response to gland pressure.
3. Distributes frictional load over several diagonally wrapped metallic sheets.
4. Originated by DURAMETALLIC.

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do little research are small compared with the cost of research that would have been required to provide immunity or to balance royalties paid with royalties received, but large compared with the cost of prosecution of patents to accomplish this result. Failure to protect inventions with patents means not the saving of patent prosecution expense, but the loss of many times this amount of money.

Patents

Companies differ widely in their patent policies. One company may not be concerned with the licensing of inventions to others for royalties, whereas another company may do this sort of thing on a large scale. The less aggressive company can defend itself only with patents, and its patent position must be made stronger than that of its more aggressive competitor. This is merely another way of saying that its technical position must be stronger than that of its competitor; for patents are, after all, merely inexpensive handles with which to wield the technical weapons effectively.

Under some circumstances, product patents can be even more important than process patents. It happens that most product patents in the chemical industries now refer to relatively small volume products, but there are some important exceptions. Here again research is justified, not by immunity, but by getting products on the market before instead of after our competitors. If we grant that research expense can be justified in this way, it is proper to balance against royalties only patent prosecution expense.

Product patents are of more value to the company with the less aggressive patent policy than to the company with the more aggressive patent policy because it takes more good patents to defend than to attack. Furthermore, there are more offensive patent alliances than there are defensive ones.

The evaluation of research in accordance with the foregoing principles requires a certain measure of optimism, but this is, after all, the same sort of optimism that inspires a company owner to believe that his company can survive as a business enterprise. For only through successful research is ultimate survival possible.

Sullivan Is Technical Director of Gas Institute

Frederick W. Sullivan, Jr., has been appointed technical director of the Institute of Gas Technology, Chicago. Since 1940 he had been manager of chemical research of the Barrett division, Allied Chemical & Dye Corporation.

The institute is located at and affiliated with the Illinois Institute of Technology.

Faust Promoted by Socony-Vacuum

Walter L. Faust has been elected a vice president of Socony-Vacuum Oil Company in New York. Since 1938 he has been sales manager for the Eastern District. He joined the Vacuum Oil Company in 1929 and subsequently rose to the managership of the marine sales department, and when that company was merged with Standard Oil Company of New York in the formation of Socony-Vacuum organization he held the same position in the merger.

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with Bourdon tube built of special alloy steel—turned, ground, and micrometer sized—stress relieved and tempered. Precision movement has phosphor bronze bushings and a wide-face cast sector with accurately cut gear teeth. Modern, easy-reading dial.
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RELIEF VALVES
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POP SAFETY VALVES
Series WTN is a top guided valve, featuring high lift and high discharge capacity. The working parts are of symmetrical design, resulting in uniform heat transfer from one working part to another, thereby eliminating distortion. Available in full throat and semi-nozzle types. Electric cast steel bodies with trim to meet service requirements for steam, air or gas. An outstanding value.
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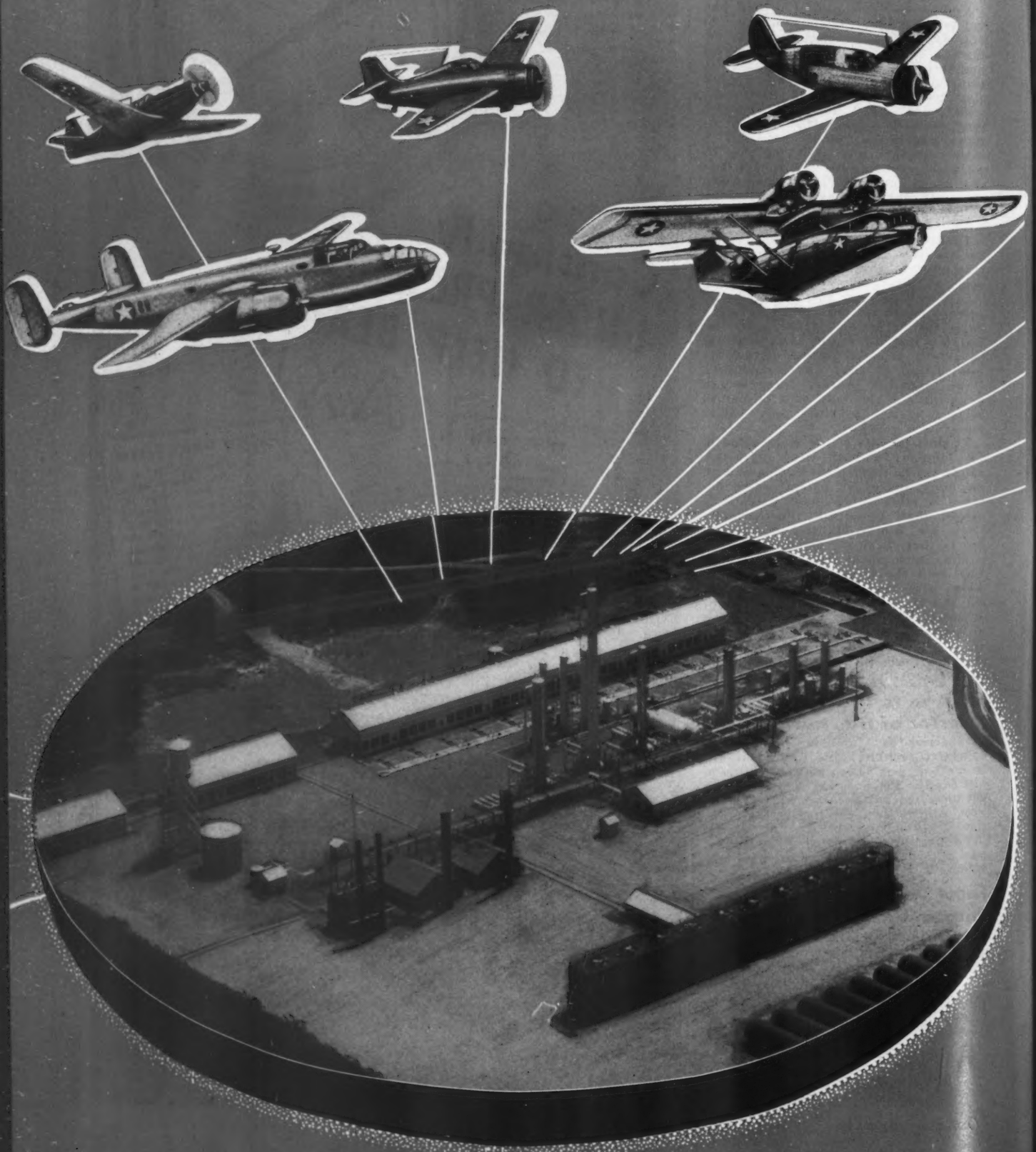


NGAA Names Technical Advisory Committee

Correlation of petroleum refining and chemical technology with the natural gasoline and distillate operating phases of the petroleum industry will be undertaken by a research planning committee, which has been named by the Natural Gasoline Association of America. R. C. Alden, director of research, Phillips Petroleum Company, is chairman.

Members of the committee are: H. H. Beeson, vice president, Sabine Valley Gasoline Company, Shreveport; H. E. Felt, vice president, Warren Petroleum Corporation, Tulsa; Dr. O. L. Roberts, The Atlantic Refining Company, Philadelphia, and C. R. Williams, The Chicago Corporation, Corpus Christi.

Objectives of the committee were outlined by Ray E. Miller, president of the association, as follows:

"The pace of technical advance of all refining process has been accelerated by war demands for rubber, aviation fuels and synthetic chemicals. While some of these products are not new, they are no longer merely expensive laboratory curiosities but are being made commercially feasible through advances in manufacturing technique.

"Stimulus for their development has been the pressing demands of total war and out of it will come completely new conceptions for the oil industry. The basic hydrocarbons from which these new products are being made are found in greatest quantity and can be most inexpensively extracted from products of natural gasoline plants. It is only natural, therefore, that we should make every effort to fit our industry into these fast-moving trends. The function of the new Research Planning Committee will be to study the highly involved technical programs and to recommend the most practical courses for the industry to pursue."

Grease Institute Program Announced

The program for the annual meeting of the National Lubricating Grease Institute in the Roosevelt Hotel, New Orleans, October 26, 27 and 28, is:

"The Proper Application of Lubricating Greases to Machinery," Charles Kraus, Alemite Division, Stewart-Warner Corporation.

"Army Grease Developments," Walter Ainsley, office of chief of Ordnance Division.

"The Flow Characteristics of Lubricating Greases," A. Beerbower, L. W. Sproule, J. B. Patberg and J. C. Simmer, Esso Laboratories.

An address by Ralph Nicholson, publisher, New Orleans *Item*.

"Survey of Lubricating Grease Test Methods," C. W. Georgi, Enterprise Oil and Grease Corporation.

"The Railroad Aspect of Lubricating Greases," Charles B. Bryant, Southern Railroad System.

"A Review of Rust Preventives and Suggested Plan for Their Evaluation," S. L. Bishkin, Humble Oil & Refining Company.

"Change in Grease Manufacture Which Is Necessary Due to the Government's Need for Additional Quantities of Glycerine," representative of the United States government.

"Lubricants for Anti-Friction Bearings in War Service," O. L. Maag, Timken Roller Bearing Company.

THE LOOK BOX

C. L. Brown, Chairman ACS Petroleum Division

C. L. Brown, Standard Oil Company of Louisiana, was elected chairman of the petroleum division of the American Chemical Society, whose annual meeting was held in Buffalo, September 7 to 11. He succeeds J. K. Robert, Standard Oil Company (Indiana), Whiting. The vice chairman is R. E. Burk, Standard Oil Company of Ohio, Cleveland.

L. M. Henderson, The Pure Oil Company, Chicago, who succeeded Carey L. Wagner when he went to OPC, was elected secretary-treasurer.

These officials, along with the retiring chairman and S. S. Kurtz, Sun Oil Company, Philadelphia, make up the executive committee.

Hightower Joins OPC Refining Division

J. V. Hightower, who has been on the staff of PETROLEUM REFINER with headquarters in New York for the past 18 months, has joined the staff of the Division of Refining, Office of the Petroleum Coordinator for War in Washington.

Hightower is a graduate of the University of Texas in chemical engineering. He was with Humble Oil & Refining Company at Baytown and later with M. W. Kellogg Company, New York, previous to his connection with PETROLEUM REFINER.

CONVENTIONS

OCT. 15–16	American Institute of Mining and Metallurgical Engineers, Petroleum Division, Hotel Ambassador, Los Angeles.
22–23	Society of Automobile Engineers, Midwest Fuels and Lubricants Meeting, Tulsa.
25–29	National Lubricating Grease Institute, New Orleans.
27–29	National Safety Congress and Exposition, Hotel Sherman, Chicago.
29–31	American Institute of Mining and Metallurgical Engineers, Petroleum Division, Austin, Texas.
30	Western Petroleum Refiners Association, Regional Technical Meeting, Washington-Youree Hotel, Shreveport.
NOV. 6	California Natural Gasoline Association, Los Angeles.
9–13	American Petroleum Institute, Palmer House, Chicago.
16–18	American Institute of Chemical Engineers, Netherlands Plaza Hotel, Cincinnati.
24–29	American Chemical Society, National Chemical Exposition and Conference, Hotel Sherman, Chicago.
30	American Society of Chemical Engineers, New York.
DEC. 1–4	American Society of Mechanical Engineers, New York.

NPA Hears of War Influence on Oil

Influence of war activity on the oil industry was the theme of the annual meeting of the National Petroleum Association in Pittsburgh, September 18 and 19. Ralph K. Davies, deputy petroleum coordinator, gave his interpretation of this influence on the industry as a whole. Bruce K. Brown, assistant deputy coordinator, dealt with influence on refining, especially plant expansion. Economic changes were analyzed by John D. Gill, The Atlantic Refining Company. Other speakers were General W. B. Pyron, liaison officer for petroleum; Lieutenant Commander W. C. Latrobe, U. S. N.; Major John L. King, and Hallett Abend, correspondent for the New York Times in the Far East.

Officials elected are: Harry A. Logan, vice president United Refining Company, Warren, Pennsylvania, president; Walter R. Reitz, secretary and treasurer of Quaker State Oil Refining Corporation, Oil City, executive vice president; J. B. Fisher, vice president Kendall Refining Company, Bradford, first vice president; W. S. Zehrung, president Pennzoil Company, Oil City, second vice president.

Under the title, "Things to Come," Davies said:

"One prospect I see clearly is the need for greater unitization of industry operations. By this I mean the joining together of normally separate entities to accomplish a sharing or joint use of facilities and resources. As shortages of materials and later of manpower force a greater economy in the immediate physical operation, the oil industry must come more and more to operate as a unit. The identity of the individual operation must by many points be submerged to attain a greater return from a lesser expenditure.

"Winning this war requires maximum production with absolute minimum expenditure of materials and men. To accomplish this, industry's good reputation is by no means enough. Indeed, whether on the gigantic scale of the present war an eventual record can be achieved remains to be demonstrated . . . although the job is well started, it is yet to be done.

"We must recognize the need for intelligent governmental direction and look critically to see that it is forthcoming.

"We cannot prevent casualties in oil ranks, because adjustments are too broad in their effect and too severe to admit of the preservation of all units on all fronts; but we must hold the casualty list to a minimum. At present, so far as lies within our influence, principle and fair play must be observed. Each particular situation is a problem in itself which can only be specifically dealt with in the light of all the facts."

Regarding products, Davies said, they must be standardized to uniform specifications for common use. "Frankly I can see no escape from the suspension of certain brand distinctions during the war period."

Increasing demand for certain petroleum products presents a serious problem to refiners, which they must meet largely with existing equipment and fewer skilled personnel, Assistant Deputy Coordinator Bruce K. Brown asserted in an address, "Petroleum Refining in 1943."

"In the fall of 1941," Brown said, "the

nation's capacity to increase the refining of petroleum probably would have been prophesied as at least 200,000 barrels per day, with no thought of any difficulty in physically supplying crude petroleum within continental United States, or that materials could not be spared.

"We're in for a long war, requiring tremendous civilian effort. The job we have ahead of us can best be defined as doing more with less.

"We must have more fuel oil, aviation lubricants, aviation gasoline, toluene, and, in certain localities we must have more coke. We must have less maintenance and repair, operate without replacing units, make and sell less motor gasoline, operate on less crude. We must operate with fewer skilled personnel — our only hope of replacing them is in training new operators selected from our present personnel.

"There must be more care used in forcing existing equipment to its ultimate capacity, more careful inspection for safety's sake, more ingenuity in converting spare equipment to new uses. Management and supervisors, at least, must work longer hours. Their personnel must see if some equipment made without better facilities 20 years ago, cannot again be made that way.

"Increased productivity has come from ingenuity and sometimes sacrifice, and the conversion of existing refinery equipment.

"Just now isobutylene is very much needed. Some isobutylene is already finding its way into war products, but about 6000 barrels a day of additional isobutylene, as di-isobutylene or selective polymer, is urgently required for aviation gasoline and if and when this need is satisfied very large additional quantities can be allocated to the manufacture of butyl rubber or flexon.

"We shall need very large quantities of benzene within the next few months, and I commend that we devise methods for producing and purifying benzene in our refineries.

"Needs of the United Nations for 100-octane gasoline eventually will exceed the productive ability of all aviation plants now built, building or authorized.

"The rubber survey committee has endorsed the making of 100,000 tons of butadiene per year. It would be an error, however, to consider butadiene manufacture as the principal justification of such a program.

"To the extent that we can produce war materials, purify them, and react them into finished products by using the nation's existing refining equipment, we can perform a triple service: (1) produce vitally needed war materials, (2) produce them the fastest way, (3) produce them with a minimum drain on the nation's capacity to produce direct engines of war."

The number of grades of petroleum products have been reduced to the absolute minimum, General W. B. Pyron, liaison officer for petroleum, War Department, asserting in explaining that rigid specifications were necessary because one grade of motor fuel must be used for many sets of conditions. With a dozen different kinds of oil, you might get the wrong oil when refueling at night. The specification must be high, he stated, because war does not permit warming up a motor.

Speaking on "Wartime Changes in the Petroleum Economy," John D. Gill, Atlantic Refining Company, said that due to war the profits trend has been downward nearly as low as in the 1938 depression year.

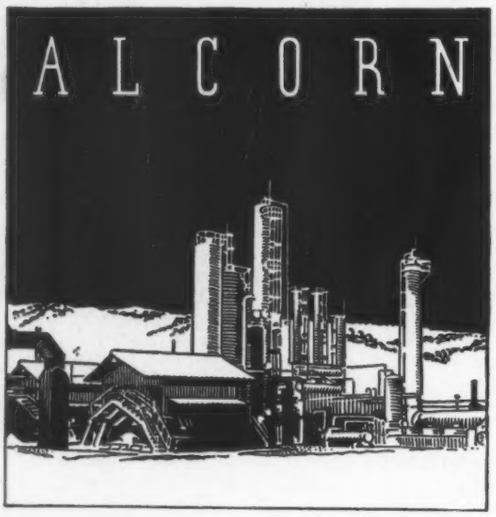
Wartime changes, said Gill, are (1) changes that make a permanent imprint on industry; (2) changes affecting different sections of the country and different branches of the industry.

One change in our competitive system is the altered transportation pattern. The effect is inevitable: (1) A reduction in cost of doing business, (2) we must do more-and-more with less-and-less.

Fate of well-established refineries is controlled by technological increase, Gill said. Fate of less-progressive refineries is controlled by relations between cost to produce crude oil and value of competitive fuels.

Our competitive structure, said Gill, is altered probably permanently by discontinuance and abandonment of retail outlets for sale of petroleum products. Three fourths of our retail gasoline outlets must give manpower to wartime industry, concluded Gill. There is crude oil enough for military, industrial, and civilian needs. Most notable of all changes in the petroleum economy are those coming from control over operation of industry by governmental agencies. Most important control is over prices of raw materials. Achievement of coordination has been the greatest difficulty in the work of government agents in the petroleum industry.

THE CHEAPEST WAY TO GET BEST RESULTS IS WITH THE PROPER HEATER



EVEN where first cost seemed higher, we have yet to see a case where the best heater was not finally the cheapest. And this observation is over a period of eighteen years' experience in all types of installations, under all sorts of conditions. The selection of the right heater is not a simple problem. We will be glad to help you solve it.

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PREVENTS LOCALIZED OVERHEATING OF OIL AND SOLVENT MIXES

DOWTHERM A GREAT AID IN VITAL PETROLEUM PROCESSES

The various processing operations of the petroleum industry, with their wide variations in heat load, provide the ideal field for DOWTHERM* indirect heating. This system for high temperature processing functions with a condensing vapor for the transmission of heat and offers, among its many advantages, close regulation of temperatures, minimum danger of localized overheating and a reduction in costly equipment.

DOWTHERM has demonstrated its usefulness in a wide variety of successful industrial installations. In the petroleum industry it is well adapted for applications in the following processes:

1. Heating and reboiling of naphthas, kerosenes and gas oils for production of special products.
2. Close fractionation of gasolines for the production of narrow boiling range, high octane cuts.
3. Finished oil rerun or solution reduction units when loss of color must be avoided.
4. Selective catalytic polymerization for the production of iso-octane where reboiling temperatures during processing approach 475° F.
5. Recovery systems of solvent refining units.
6. Distillation or stripping of rich absorption oils in recovery plants.
7. High vacuum distillation of lubricants.

We invite inquiries and will be glad to discuss with you the application of a DOWTHERM system to your own heating operations.

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Refiners Consider Plant Protection at Tulsa Session

Western Petroleum Refiners Association met in special session in Tulsa September 24 to consider protection of refineries, gasoline plants and related equipment in times of war. Lieutenant Colonel Arthur H. Denison, air-plant-protection officer, Mid-Western Procurement District, Wichita; addressed the meeting on "The Importance of Protecting Petroleum Facilities in Time of War." Following this paper, the meeting was opened for discussion of problems and for the consideration of suggestions in line with the protective effort of the association. As a forward step in promoting plant safety in these times, it was recommended by the more than 50 present that future meetings of technical men, operators and engineers be held and that such men offer any suggestions bearing upon any phase of the subject.

Colonel Denison emphasized that protection is wholly a problem of the industry. The military, however, is empowered to enforce protection of essential commercial and industrial establishments. He explained that such essntial concerns or plants are listed as P-1, P-2 and P-3, with the P-1 designation indication the most essential. His office makes recommendations (limited to this procurement area which roughly includes the Mid-Continent producing sector) and inspects precautions taken. Recommendations are made on the basis of (1) reduction of possible delivery irregularities by decreasing dangers or other sources tending to reduce these scheduled deliveries, and (2) raise standards so that necessary output is available during war and so that this standard is obtained following war.

It was pointed out that with the present increase in plant output, involving as it does an increased number of shifts and unit hours worked, normal accidents should increase. This has followed and should correctly be attributed to increased plant activity rather than to some outside source. In addition, with armed forces taking many experienced men, green hands are being trained to take over jobs, and these inexperienced helpers are more liable to accidents than those more practiced in the lines considered. It was to be remembered also that an oil refinery has 100 points at which serious fires can start to every 3 such points in other industrial plants.

Asked as to practice blackouts in the upper Mid-Continent area, the Colonel stated that he did not feel that regular blackout practice was desired in the area. Plant managements should, however, ascertain how much time might be required to obtain an effective blackout. Also, the management should determine or make available the equipment necessary to effective plant blackouts in case such would be required on short notice in the future. It was felt that the greatest present danger is from fires of whatever origin, employe failure and from personnel error.

John Day, secretary of the association, mentioned the work that has been done along the Western and Gulf Coasts, stating that because of their position they had experimented with protective ideas that might find application in other areas. Among other efforts he spoke of smoke from flumes and smoke derived from burning waste oils in ditches dug to windward of the plants. He suggested that ideas similar to these would be welcome.

C-B *High-Pressure* CONDENSATE RETURN SYSTEM
for REBOILER CONDENSATE DRAINAGE

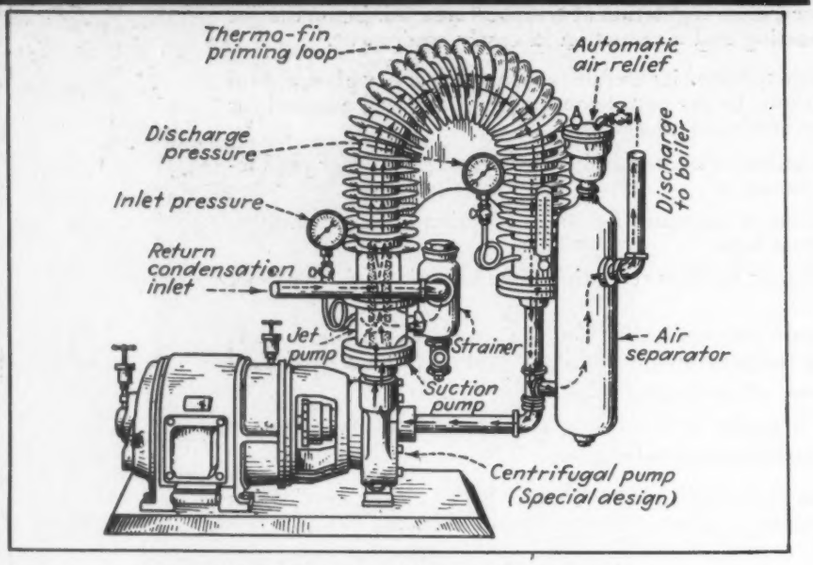

Diagram showing how the pumping unit of the Cochrane-Becker high-temperature condensate-return system operates.

EXCLUSIVE JET PUMP DESIGN

OPERATES IN A CLOSED CIRCUIT.

MAINTAINS PRESSURE DIFFERENTIAL across process equipment, with discharge of condensate against higher pressures without FLASH LOSS or necessity for high static suction head — flash tank — float control or auxiliary pump.

INCREASES EFFICIENCY — assures constant evacuation of condensate and entrained air from equipment — maintains maximum, uniform heat transfer rates.

LOWERS STEAM COSTS — by direct return of hot condensate to waste heat boiler — surge tank or pressure return line to boiler plant.

AUTOMATIC IN OPERATION.

SUBMIT PROBLEMS without obligation — Ask for Publ. #3025

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Compact Sessions Stress Natural Gas

Conservation of natural gas was considered at the quarterly meeting of the Interstate Oil Compact Commission, Chicago, October 2 and 3.

The expansion of pipe-line facilities, developments in the liquefied-petroleum-gas industry, Bureau of Mines research, technical developments in gas synthesis, gas utilization for synthetic production, and natural gas conservation, all received attention of the 75 in attendance.

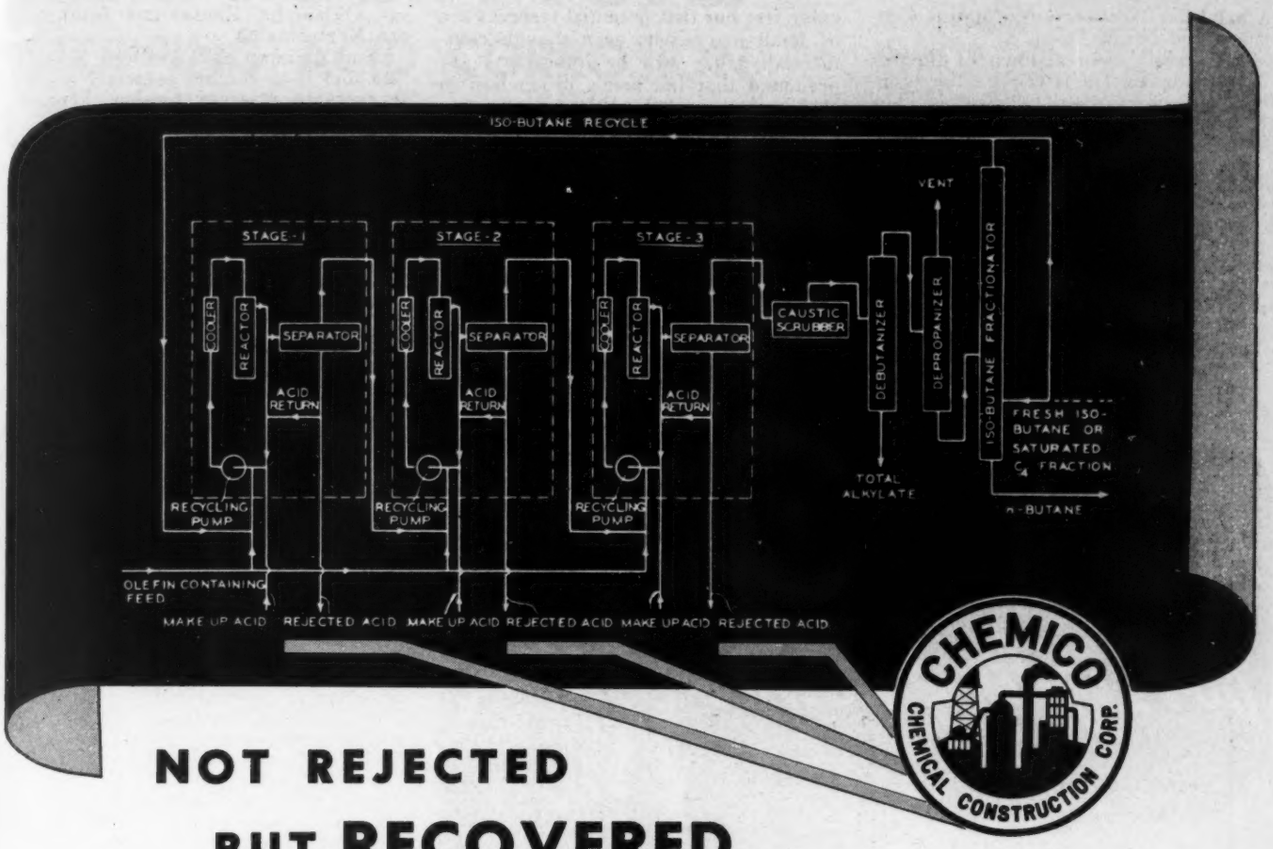
Harold L. Ickes, petroleum coordinator, spoke briefly, his remarks were off the record.

First speaker at the compact meeting was Ralph E. Davis, natural gas consultant of Pittsburgh, who assured commission members that the known gas reserves today are greater than at any previous year, totaling about 85 trillion cubic feet.

Gas Reserves

"This statement is based upon the fact that in every recent year very substantial additions to the known natural gas reserves have been made and in amounts annually exceeding the total gas withdrawals," he said.

In this connection he called attention to a comparatively recent discovery of a large, high-pressure reserve along what is known as the Wilcox trend in



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a belt that crosses South-Central Louisiana and South Texas.

To present a breakdown of the nation's reserves, Davis divided the country into five districts, Appalachian, North - Central, Mid - Continent - Gulf Coast, Rocky Mountain, and California.

He pointed out that the Appalachian area, including New York, Pennsylvania, West Virginia, Ohio and Kentucky, had produced about 16 trillion cubic feet of gas at the end of 1940, exclusive of wastage, and that gas in this region has been obtained from more than 30 separate horizons. In 1940 the area produced 385 billion cubic feet and in 1941 production was probably slightly in excess of 400 billion cubic feet, he said. Davis estimated the Appalachian district has proven reserves of 5 trillion cubic feet but that potential reserves are of small magnitude, even though commercially they will be important. He predicted that the area's production in 1942 would equal the 1941 output.

In the North-Central area he included Michigan, Indiana and Illinois, which produced about 270 billion cubic feet between 1906 and 1940. Known recoverable reserves of the area are only 200 billion cubic feet, he said, principally because of the uncertainty of conservation becoming effective in Illinois. Prospective reserves are judged to be of a similar amount.

Davis referred to the Mid-Continent-Gulf Coast region as the great storehouse of presently known reserves. The area includes Texas, Louisiana, Arkansas, Oklahoma, Kansas and Southeastern New Mexico.

"Summarizing this district," he said, "we find it to contain presently proven recoverable reserves totaling approximately 70 trillion cubic feet."

He pointed out that an estimate of ultimate potential reserves would be but a guess and then predicted they would be of an order approaching the present-known reserves.

Davis declared the Rocky Mountain States have known reserves approximating at least 750 billion cubic feet.

"Substantial additional reserves should eventually be discovered in this broad region by further development of known structures and discoveries in possible areas not yet explored," he states.

Davis estimated California's recoverable reserves at 9 to 10 trillion cubic feet and said that additional reserves should be found with deeper drilling in present fields.

"If the preceding statements and analysis of the natural-gas-reserve situation in the various districts of the United States be at this time a fairly correct picture we may note that the total proven reserve is of the order of 85 trillion cubic feet and that potential reserves, difficult at best to visualize quantitively, may be of a similar quantitive order," he declared.

It is unfortunate, Davis said, that developed and potential reserves are relatively small in certain regions where the demand for gas is great.

"It is to be expected that this situation will within reasonable time and as the conditions permit, be overcome in part at least by the installation of new transmission facilities so that gas may be taken from areas of super-abundance to areas strong in demand but short in supply."

He added that natural gas marketed in the United States has increased more than threefold in the past 20 years and that unless "everything goes haywire," this trend should continue.

Davis advocated wide-scale conservation as a move essential to maintain the immense and increasing flow of gas, but also said great improvements in efficiency of use already have been made.

Gas Lines

The other speaker Friday morning was N. C. McGowen of Shreveport, president of United Gas Corporation. His subject was "Pipe Line Systems for Natural Gas."

McGowen said pipe-line expansion, "must not be on the business-as-usual lines." He pointed out that between 1928 and 1941, pipe lines transporting natural gas were expanded from 57,000 to 90,000 miles. In the same period the number of communities served with natural gas increased 200 percent.

McGowen said that known gas reserves of 80 trillion cubic feet and the 1941 demand of three trillion cubic feet indicated a natural gas life in excess of 25 years. He advocated the continued drilling of gas wells. "The pipe lines, in figuring their demands for gas must require producers to carry on a continuous drilling program to meet the normal demands and also to maintain sufficient delivery capacity to meet demands brought on by increased industrial loads," he said. He added that it was apparent transmission facilities must be expanded but "our expansion must be weighed at present to that

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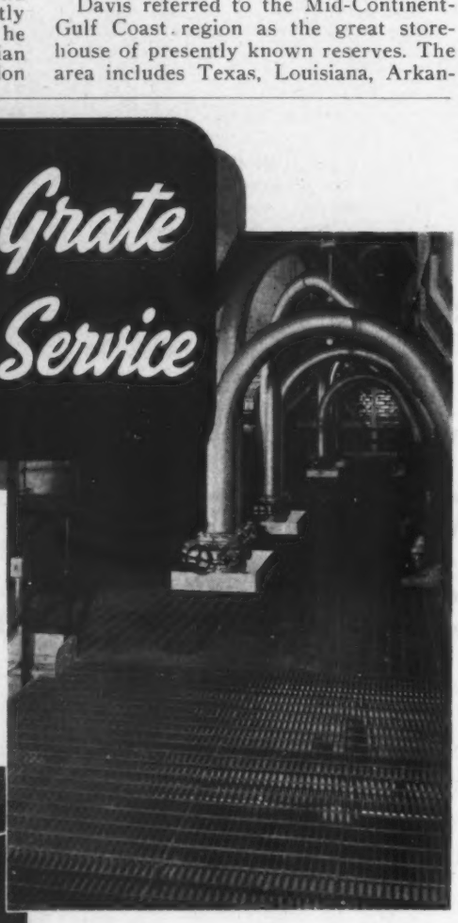

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1. Pfaudler glass enamel is resistant to *all acids,* except hydrofluoric. It stands up where many "tough" alloys have failed. It prevents undesired catalysis, remains inert to acid solutions.

2. It withstands temperatures up to 600°F., is resistant to thermal shock.

3. The bond or adhesion of Pfaudler glass enamel to its metal base is approximately 3000 pounds per square inch minimum.

4. Internal and jacket pressures of Pfaudler glass-lined units have been upped continuously. Internal pressures of 300 pounds per square inch are possible. Laboratory autoclaves have been built for 1000 pounds internal pressure.

5. *Standardized* reaction kettles for both high and low pressure work are available in a wide range of capacities.

6. Special shapes and designs to meet new operating conditions have become more diversified.

7. With Pfaudler acid resisting glass-lined pipe, fittings, and valves, you can process in the complete absence of metal.

8. The smooth seamless surface of Pfaudler glass enamels minimizes adhesion.

9. In certain processes, the substitution of Pfaudler glass-lined steel has conserved many critical materials of construction for the war effort.

10. Pfaudler engineering has solved many a tough process equipment problem. Is yours next?

TYPICAL EXAMPLES OF HOW THE OIL INDUSTRY USES PFAUDLER GLASS-LINED STEEL EQUIPMENT

SYNTHETIC RUBBER

Pfaudler Glass-Lined Polymerizers are the standard specification in synthetic rubber production lines. The smooth, seamless surface minimizes adhesion during this all-important step. The glass lining prevents reaction between equipment and contents.

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Several companies treat gasoline with cupric chloride to remove the mercapatans in Pfaudler glass-lined process tanks. These tanks are built to withstand a 50 lb. internal pressure.

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Some refineries use Pfaudler Glass-Lined chlorinators for chlorinating wax. In this type of service Pfaudler's resistance to acid corrosion is especially important. One company handles moist H_2S at 400° to 450°F., in Pfaudler Glass.

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Pfaudler Glass-Lined laboratory equipment is widely used for experimental work. With it you can use higher pressures at elevated temperatures without danger of corrosion or undesired catalysis. Many companies use glass-lined steel in all phases from laboratory to pilot plant to full scale production.

PFAUDLER

which is absolutely necessary and essential to the war effort."

E. H. Poe, director of the Natural Gas and Natural Gasoline Division of OPC attended Friday's session. Although he did not appear on the program he said in an interview that gas-producing states must adopt modern and uniform laws relating to production and conservation of gas. He called present gas conservation laws obsolete and useless, and expressed opposition to the Oklahoma law which provides that only 25 percent of a field's daily potential production can be actually produced daily. "There is grave shortage of natural gas," he said.

"In addition there is a serious pipeline shortage for getting the gas from the field to the consumer, whether that be householder or industry." He advocated the adoption in each state of laws which will provide for the taking of gas from the fields according to the structure of the fields.

Friday afternoon a technical forum was conducted by the research and coordinating committee at which Frederick W. Sullivan, Jr., technical director, explained the operation and organization of the comparatively new institute of gas technology at Chicago, which was formed in 1941.

Primary functions of the institute, according to Sullivan, are to train personnel, to carry out and encourage research and to distribute information concerning gas. The institute is supported by member companies which are divided into two groups—utilities and appliance and equipment manufacturers. The educational program is designed to provide study leading to degrees of M. S. and Ph.D. with special study in gas technology. At present the fundamental research activities of the institute are concerned with the broad fields of catalysis and absorption, Sullivan explained.

Dr. Gustav Egloff, director of research for Universal Oil Products Company, Chicago, discussed "Present and Future Gas Utilization for Synthetic Products," at the Saturday morning session.

The other Saturday speaker was G. L. Brennan, manager of the liquefied petroleum gas division of Warren Petroleum Company, Tulsa. His subject was "Development of the Liquefied-Petroleum-Gas Industry." He declared large volumes of liquefied-petroleum-gas formerly wasted, now are being conserved for important uses and predicted that during 1942 nearly 2,000,000 gallons of propane will be produced and sold daily.

"To what extent normal butane will be used in the manufacture of butadiene for rubber is still a big question, possibly much of the proposed refinery-conversion program suggested will use other petroleum fractions—nevertheless normal butane remains an important raw material for the production of synthetic rubber."

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Institute of Gas Technology Adds Three Staff Members

The Institute of Gas Technology, located at Illinois Institute of Technology, Chicago, has opened its second academic year with three new staff appointments and 10 new fellows, Director Harold Vagtborg has announced.

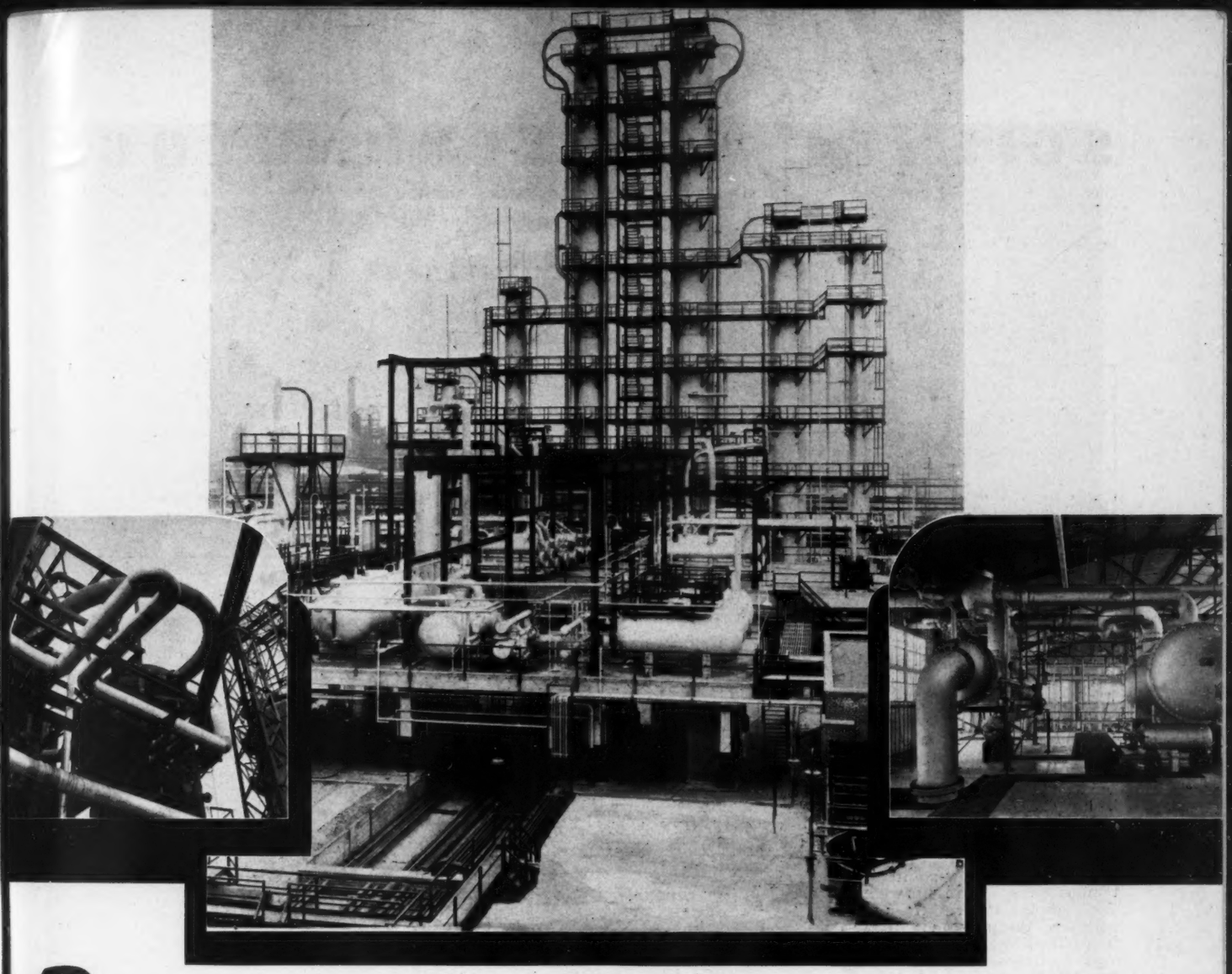
New appointments to the staff are Dr. F. W. Sullivan, Jr., technical director, and A. D. Singh and Orin D. Cunningham, research associates.

Dr. Sullivan holds B.S., M.S. and Ph.D. degrees from the University of Michigan. He was director of chemical research for the Barrett Division, Allied Chemical and Dye Corporation, before coming to the Gas Institute. Dr. Sullivan's coming to Chicago is a homecoming for him, as he was formerly director of research for Standard Oil Company (Indiana).

Singh has been research assistant in chemical engineering at the University of Illinois for the past 10 years. He has also served as technical adviser to Chicago's department of smoke inspection and abatement. He holds B.S. and M.S. degrees from the University of Illinois.

Cunningham holds B.S. and M.S. degrees from Northwestern University and Montana, respectively. He was formerly on the research staff of the Reilly Tar and Chemical Company in Indianapolis.

The new fellows and the institutions from which they were graduated are: Willard M. Dow, Colorado School of Mines; Roy C. Feber, Jr., University of Nebraska; Alan E. Florin, Lawrence College; W. Madden Gregory, Vanderbilt University; William Johnston, University of Texas; Richard A. Nevill, Texas A. and I.; Thomas L. Pelican, Colorado College; Leonard E. Savory, University of Denver; John W. Selph, Jr., Vanderbilt; and Erwin R. Strong, Jr., Texas A. and I.



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The abstracts here presented are selected from the current literature of science and technology to afford reference to fundamental information not easily available to all readers. Abstracts of articles appearing in readily obtainable trade journals are not included.

Photostat copies of original articles will be supplied at cost by the Leslie Laboratories. Complete or limited bibliographies covering special topics by title, by abstracts, or in complete manuscript, will also be prepared and furnished at reasonable cost by the Laboratories.

Fundamental Physical and Chemical Data

Methane-Isobutane System, R. H. OLDS, B. H. SAGE AND W. N. LACEY, *Ind. & Eng. Chem* **34** (1934) pp. 1008-13.

The volumetric and phase behavior of the methane-isobutane system was ascertained for pressures up to 5000 pounds per square inch in the temperature interval between 100° and 460° F. The study included the determination of the specific volumes of four mixtures, as functions of pressure and temperature, and the experimental measurement of the composition of the dew-point gas at three temperatures. The results were smoothed with respect to pressure and temperature, and the properties of the coexisting phases were ascertained for even values of these variables. The data are presented in detail in tabular and graphical form.

Correlating Gas Solubilities and Partial Pressure Data, D. F. OTHMER AND R. E. WHITE, *Ind. & Eng. Chem.* **34** (1942) pp. 952-59.

Gas-liquid equilibrium or solubility data are of fundamental importance in the study of any gas-liquid absorption or desorption process. The methods of expressing these relationships are briefly reviewed. A new method of representing gas solubility data has been developed and applied to a number of gas-liquid systems. The representation is graphical and similar to the method applied to the vapor pressures of liquids. The plot is based upon the equation: $\log p = (Q/Q') \log p' + C$. A plot of this equation is made on logarithmic scales with vapor pressure of water as the abscissa, the gas partial pressure as the ordinate, and the concentration of the solution as the parameter. Data for systems that follow Henry's law closely and for systems that deviate from it widely have been plotted in this manner with equal success. In every case the data give lines that can be considered straight within experimental accuracy or lines made up of straight sections of different slopes. An abrupt change in the slope of a line indicates a change in the chemical form in which the gas exists in solution. The straight lines or straight-line sections support the applicability of the plot and also indicate the constancy of the ratio Q/L over ranges involving no chemical change in the gas. From the basic equation the variation of the Henry law constant with temperature can be developed and represented graphically in the same manner. Heats of solution of gases in liquids may be evaluated readily from the slopes of the lines. This is particularly useful because of the few experimental data available for this important thermal quantity.

The Compressibility of Liquid n-Octane, W. A. FELSING AND G. M. WATSON, *Jour. Amer. Chem. Soc.* **64** (1942) pp. 1822-23.

The compressibility of liquid n-octane was determined at 25° C. intervals from 100° to 275° C. at pressures ranging from the vapor pressures to approximately 300 atmospheres. The data are presented in some detail in tabular and graphical form. The uncertainty in the measurement of pressures was less than 0.03%, in the determination of mass less than 0.01%, and in the measurement of volume 0.05 to 0.1%. The temperature measurements were correct to within 0.01% C. There was evidence of slight decomposition at 250° and 275° C.

Viscosity of Propane, Butane, and Isobutane, M. R. LIPKIN, J. A. DAVISON, AND S. S. KURTZ, JR., *Ind. & Eng. Chem.* **34** (1942) pp. 976-8.

The authors determined the kinematic viscosity of liquid propane from —105° to +70° F., of n-butane from —105° to +100° F., and of isobutane from —105° to +48° F. The viscosities were determined with an accuracy of ±2 percent in two types of specially designed capillary-flow viscometers, one for the higher temperature range, and the other for the lower range. The apparatus and methods employed are described. The data secured are presented in tabular and graphical form. A plot of the logarithm of the kinematic viscosity of 25° C. vs. number of carbon atoms for the normal liquid hydrocarbon, gives a straight line.

The Viscosity of cis- and trans-Decahydronaphthalene, WM. F. SEYER AND J. D. LESLIE, *Jour. Amer. Chem. Soc.* **64** (1942) pp. 1912-16.

The viscosities of cis- and trans-decahydronaphthalene were measured from —30 to 180° C. When the logarithm of the viscosity is plotted against the reciprocal of the absolute temperature straight lines were not obtained. There is evidence that the cis-form undergoes some change at 110° C. The authors make an effort to explain the high values of the absolute viscosity, and also the effect of cis-trans isomerism on the viscosity. The viscometers used were modifications of the Ostwald type, made in accordance with British Standards Specification No. 188-1937. They were specially designed to reduce deviations from Poiseuille's law to a minimum.

Solvent Properties of Isomeric Paraffins, E. H. MCARDLE AND A. E. ROBERTSON, *Ind. & Eng. Chem.* **34** (1942) pp. 1005-8.

The development of high-octane gasoline production has resulted in the making of a number of stocks that contain large proportions of branched paraffins. It was thought by the investigators that if a branched octane with the same volatility of n-heptane should give rise to twice or half the viscosity in comparable solutions of a protective coating vehicle, many practical applications would at once become apparent. A preliminary survey of the matter was therefore undertaken. Solvent properties can be considered under two general classifications, namely, dilution ratio values and viscosity effects. Two dilution ratio tests were used in the investigation: the familiar kauri-butanol value and the tolerance to pure n-decanol of a solution of polybutene in the hydrocarbon under test. Two pairs of isomeric paraffins were used in making comparative solvent property tests. Viscosities were taken with the Gardner-Holdt viscometer, which precludes the loss of solvent. Two series of polymers—low molecular-weight polybutenes and alkyd resins—were used at concentrations of 800 grams per liter, with viscosities ranging from 0.1 to 150 poises. The data show that, although the solvents possess substantially the same dilution ratios, the highly-branched paraffins neohexane and triptane produce polymer solutions whose relative viscosity average more than twice those of corresponding solutions in straight-chain solvents. Corrections applied to absolute viscosities for differences in boiling point or critical temperature accentuate the spread. The

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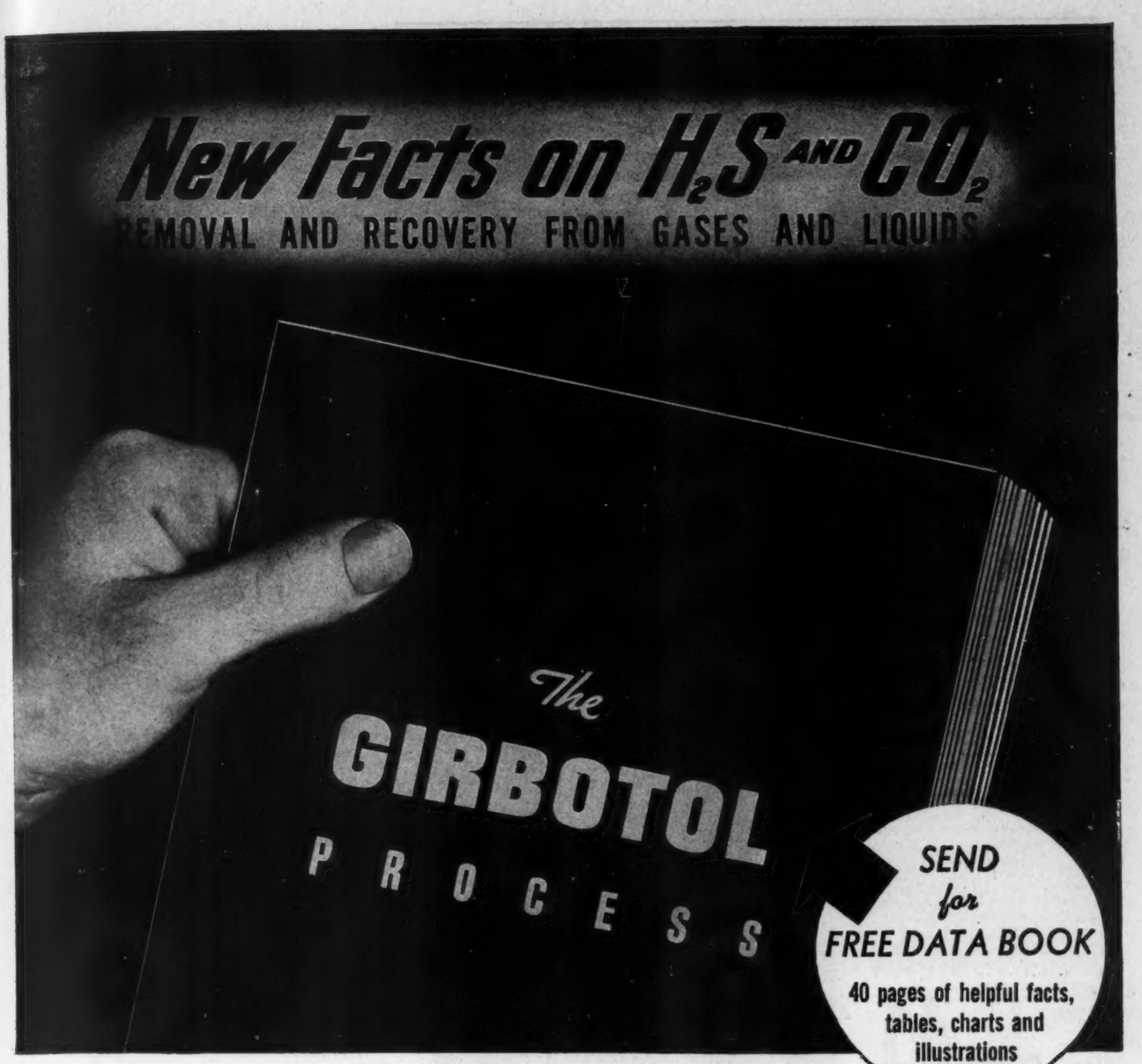

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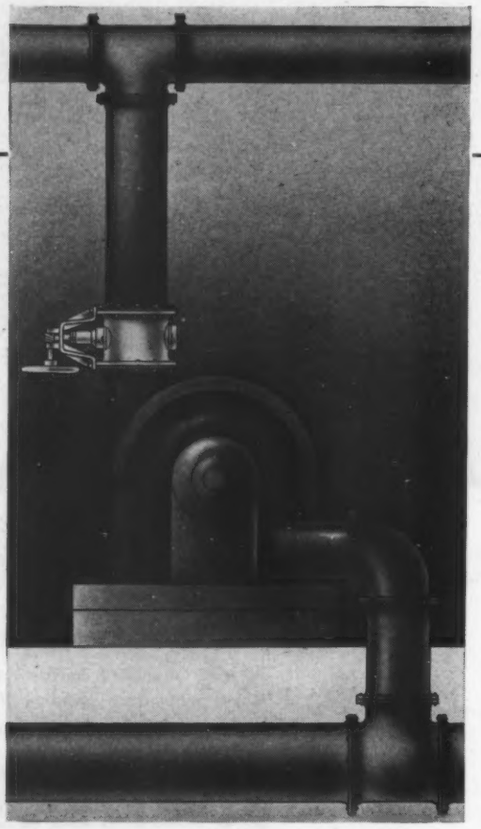

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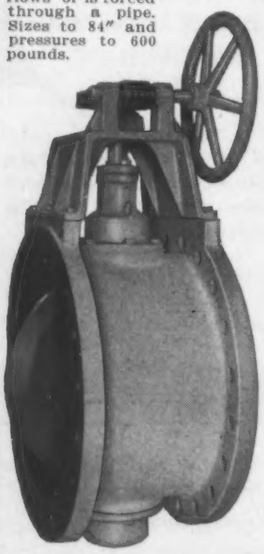

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data are presented in some detail in tabular and graphical form.

Chemical Compositions And Reactions

Higher Hydrocarbons. II. Five 11-Substituted Heneicosanes, F. C. Whitmore, J. N. Cosby, W. S. Sloatman and D. G. Clarke, *Jour. Amer. Chem. Soc.* **64** (1942) pp. 1801-3.

The methods of preparation and the physical properties of six new high molecular weight hydrocarbons are given. These include five 11-substituted heneicosanes and 11-phenyl-10-heneicosenes. The synthesis of the compounds involved the addition of an excess of n-decylmagnesium bromide to the esters: ethyl caproate, methyl 2-ethylbutyrate, ethyl cyclopentanecarboxylate, and methyl benzoate. The resulting tertiary carbinols were dehydrated over copper sulfate in an atmosphere of nitrogen. The purified olefins were hydrogenated in a pressure bomb over nickel catalysts. The properties of the compounds are tabulated, including the melting point, the boiling point, refractive index, density, molecular refraction, viscosity, and carbon and hydrogen percentage.

The Formation of Cyclopropanes from Monohalides. III. Action of Sodium Alkyls on Aliphatic Chlorides. Relation to the Wurtz Reaction, F. C. Whitmore and H. D. Zook, *Jour. Amer. Chem. Soc.* **64** (1942) pp. 1783-5.

Sodium ethyl and sodium propyl were prepared from sodium and the corresponding mercury compounds in yields of 80 and 88% respectively. No appreciable reaction took place between the alkylsodium compounds and n-paraffin hydrocarbons. Sodium ethyl reacts with n-hexyl chloride to give octane, ethane, 1-hexene, and a trace of ethylene. The products of the reaction of sodium propyl and neopentyl chloride were 1,1-dimethylcyclopropane, propane, propene, and the coupled products, 2,2-dimethylhexane. The major reaction was one of the hydrocarbon base splitting hydrogen chloride from an alkyl chloride. The possible relationship of these results to the mechanism of the Wurtz reaction is discussed.

The Thermal Decomposition of Higher Hydrocarbons, I. W. Jost and L. V. Muffling, *Z. Elektrochem.* **47** (1941) pp. 766-73.

Pressure-time diagrams and analytical results are given for the decomposition of hexane, heptane, octane, 2,5-dimethylhexane, 2,2,4-trimethylpentane, cyclohexane, toluene, ethyl benzene, propyl benzene, and isopropyl benzene. However, it is not possible to draw a definite conclusion as to the mechanism of the reactions involved. The rate of decomposition of normal compounds is doubled by the addition of one carbon atom to the chain. Increased branching of the chain causes increased formation of hydrogen, methane, propane, or propylene, whereas less methane and ethylene are formed. The addition of Me_2Hg increases the rate of methyl formation and hence the rate of pressure rise. Increase of one carbon atom in the side chain of deriva-

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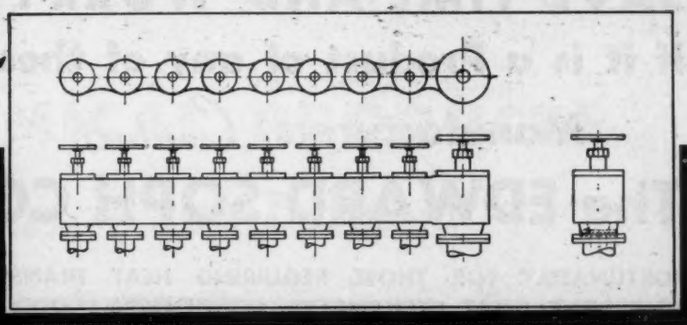

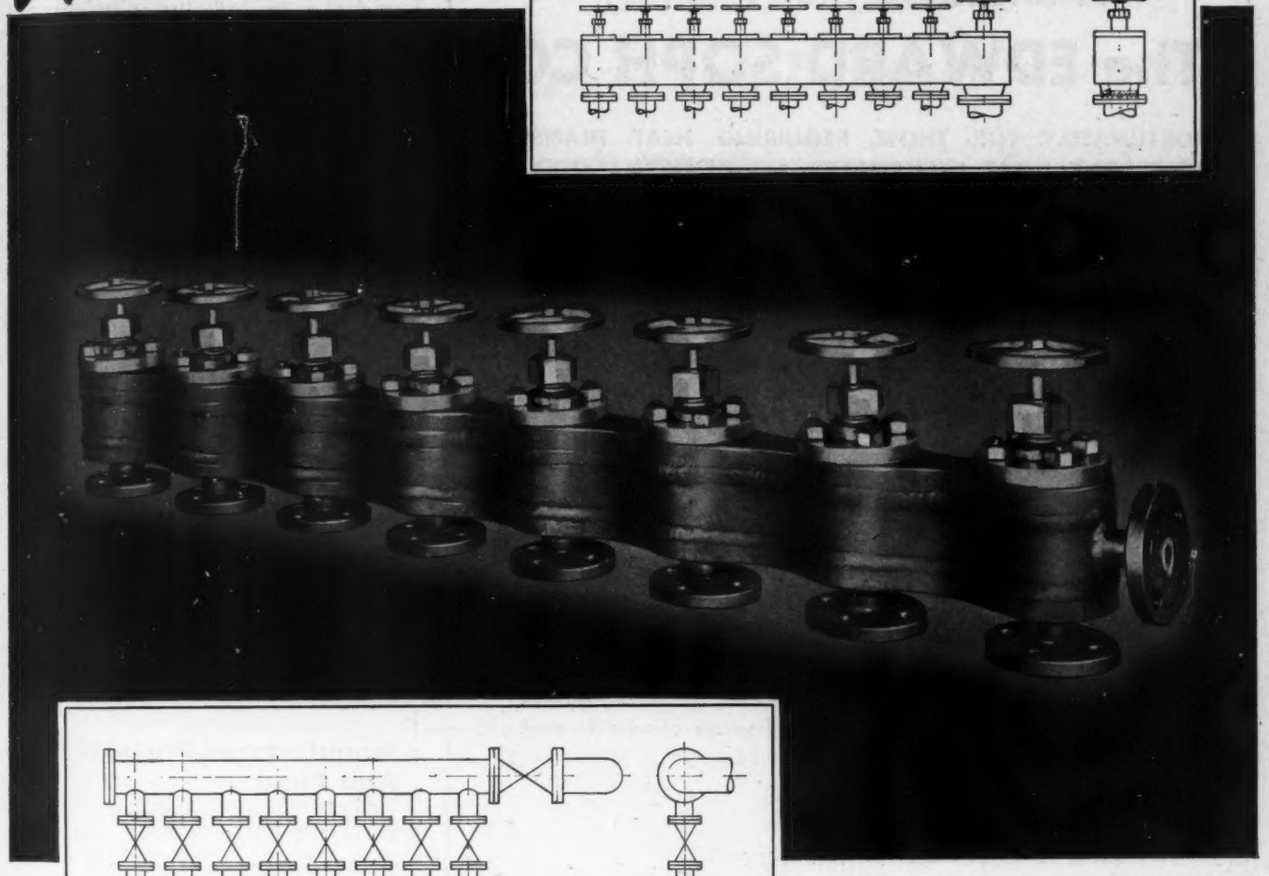

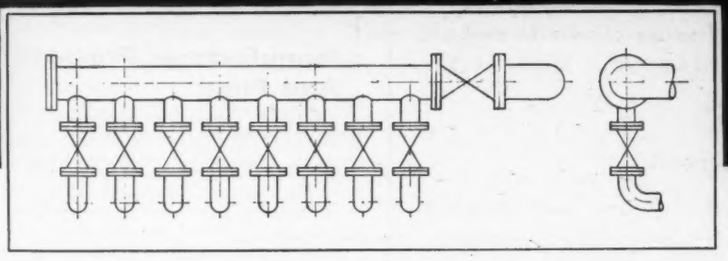

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The drawing directly above indicates the relatively complicated valve-and-piping hook-up which the welded manifold valve replaces.

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tives of benzene doubles the decomposition rate.

The Hydration of Isobutene in Dilute Nitric Acid, G. R. LUCAS AND L. P. HAMMETT, *Jour. Amer. Chem. Soc.* **64** (1942) pp. 1938-40.

The experimental results indicate that t-butyl nitrate is not an intermediate product in the hydration of isobutene in dilute nitric acid. It was concluded that the pronounced acceleration produced by nitrate ion is a salt effect. The distribution of products in the reaction of mercuric nitrate with t-butyl chloride was studied in various dioxane-water mixtures. The results indicate that the rate of disappearance of isobutene in dilute nitric acid decreases rapidly with increasing proportion of dioxane.

The Reduction of Unsaturated Hydrocarbons at the Dropping Mercury Electrode. I. Phenyl Substituted Olefins and Acetylenes, H. A. LAITINEN AND S. WAWZONEK, *Jour. Amer. Chem. Soc.* **64** (1942) pp. 1765-68.

Isolated ethylenic and acetylenic linkages are not reducible at the dropping mercury electrode. However, double bonds that are either conjugated with carbonyl groups or present in heterocyclic nuclei like pyridine and quinoline can be reduced. The authors have found that other types of unsaturated linkages are electroreducible. In the present paper the results of a polarographic study of phenyl substituted olefins and acetylenes is reported. The most suitable solvent medium was found to be a dioxane-water mixture containing 75% dioxane, with tetrabutylammonium iodide as the supporting electrolyte.

Manufacture: Processes And Plant

Crude Naphtha Stabilizer Performance, J. Q. MCGIFFIN, *Trans. Amer. Inst. Chem. Engrs.* **38** (1942) pp. 761-90.

The information and data contained in this paper are being released and published in the hope that it will stimulate discussion and interest in the subject of critical vapor and downcomer velocities in commercial bell-cap plate fractionating towers. Reference is made to literature articles on the subject. The paper reports plant data and calculated results on six full-scale engineering tests recently conducted on a complete crude naphtha stabilizer system. This tower was 42 inches in diameter, 61 feet high, and included 30 trays. A schematic flowplan of the tower and exchanger equipment, and a layout of the stabilizer plate and tower details are given. An isometric drawing of the plant, and a photograph of the equipment are also included. The tower was operated just below flooding conditions during the test periods to make as close a cut as possible between iso and normal pentane, and normal butane and iso-pentane, from a feedstock consisting of raw straight-run crude naphtha. The results obtained indicate that tower performance suffers when so-called critical or limiting vapor velocities and safe downcomer velocities are reached. Calculated results for each test include the following: (1) internal reflux at top of tower; (2) limiting vapor velocity in free area at top of tower; (3) actual vapor velocity at top of tower; (4) downcomer velocity

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at top of tower; (5) vaporization in reboiler; (6) limiting vapor velocity in free area at bottom of tower; (7) actual vapor velocity at bottom of tower; (8) downcomer velocity at bottom of tower; (9) tower performance in percent separation obtained; and (10) heat exchanger performance. Safe downcomer velocities are shown to be as high as 1.5 ft./second in some cases. Fractionation suffers somewhat when actual vapor velocities in either the top or bottom sections of the tower exceed the critical velocities as calculated by the formula:

$$V = 4.04\sqrt{\frac{TS}{MP}}$$

in which T=vapor temperatures in ° R,. S is liquid specific gravity at temperature T, M is vapor molecular weight, and P is operating pressure in pounds per square inch absolute.

Mixed Solvent Extraction, T. G. HUNTER, *Ind. & Eng. Chem.* **34** (1942) pp. 963-70.

In recent years considerable development has taken place in the use of mixed solvents for solvent extraction operations, particularly in the refining of mineral oils. In mixed solvent processes the two or more solvents employed are mutually soluble under the operating conditions, and the mixed solvent is therefore a single homogeneous liquid phase. A mixed solvent of two components is commonly used, in which one solvent component is only partially miscible with the stock mixture being treated under the prevailing operating conditions, while the other solvent component is completely miscible both with the first solvent component and the stock mixture under the operating conditions. A good example of this process is the benzene-sulfur dioxide extraction of lubricating oils. The separation of a binary mixture by solvent extraction and the refining of a mineral oil with a solvent, at constant temperature have been extensively studied and described by means of phase equilibrium relationships. These investigations have now been extended to the study of mixed solvent extraction processes, and the present paper deals with the stoichiometric computations involved in the simple separation of a binary mixture by batch extraction with a mixed solvent consisting of two components. Typical computations are included, along with several diagrams illustrating the principles involved.

Fire Protection Methods for Process Plants, CHEM. & MET. REPORT, *Chem. & Met. Engr.* **49** (1942) pp. 98-104.

So much has been published in recent months on the special fire hazards of war-time that it seems possible to the editors of Chem. & Met. that the ordinary peacetime fire hazards of the process industries may not be receiving the attention that they deserve. The present report has therefore been prepared, both to discuss the normal hazards, and to show how fires may be fought. In addition, the report considers the organization and training of the plant fire brigade, gives sources of information on industrial fire hazards, and on fire prevention and protection. Several agencies, notably the National Fire Protection Association and the Factory Mutual

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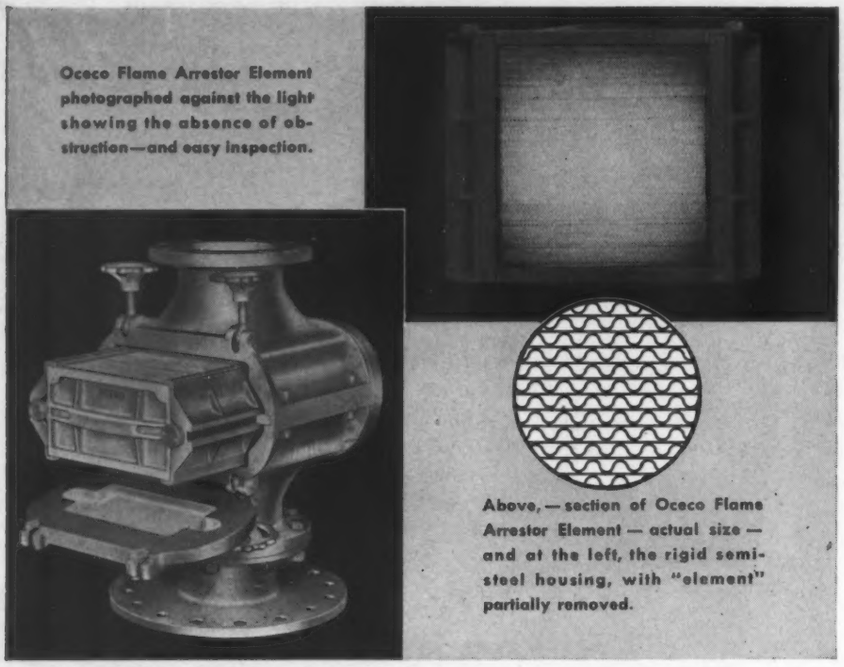
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Fire Insurance Companies Inspection Department, have cooperated with the editors in supplying the most recently available information. Other agencies also also, as noted in the article, available for advice and assistance to the end that industrial fire losses can be minimized in these critical days when every pound of production is vitally needed, and every building and piece of equipment lost may be difficult, if not impossible, to replace. Materials for extinguishing fires are considered, as well as types of extinguishers and extinguishing systems. Steam, foam, carbon dioxide, carbon tetrachloride, and dry chemical extinguishers are discussed. Permanent systems are considered, as well as various designs of sprinkler systems. A table is included showing the properties of flammable materials, including flash point, explosion range, auto-ignition temperature, specific gravity, and vapor density. Reprints of the 8-page report are available at 25 cents per copy by addressing the Editorial Department of Chemical and Metallurgical Engineering at 330 West 42nd Street, New York City.

Soil-Corrosion Studies, 1939. Coatings for Protection of Metals Underground, K. H. Logan, *J. Res. Natl. Bur. Stand.* **28** (1942) pp. 57-71. (Res. Paper No. 1446.)

The protection afforded by zinc coatings on metals underground depends upon the thickness of the coatings and is not much affected by the kind of ferrous metal to which the coating is applied. Uniformity of the zinc coating is important. Lead coatings applied to iron and steel have not proved adequate for protection underground. Since the potential of lead is cathodic to iron, lead cannot protect iron or steel cathodically in the same manner as zinc, and the rate of corrosion of lead is appreciable under many soil conditions as a continuous layer of lead isolating steel from the adjacent soil cannot usually be maintained. Tin-coated copper is susceptible to corrosion in soils that are corrosive to copper. Two hot-dipped asphalts and coal-tar coatings were found to have failed after exposure to soil for 15 years. A vitreous enamel coating and two hard rubber coatings afforded complete protection for 7 years. Baked-on bakelite varnish afforded the most satisfactory protection of all.

Special Slide Rules Can Facilitate Many Enginetring Calculations, G. T. Austin, *Chem. & Met. Engr.* **49** (1942) pp. 90-93.

Ordinary slide rules have long been important mathematical tools of the engineer. Special rules, limited in their application to the solution of a single equation, have been utilized to considerable advantage in the various engineering fields, and articles on their construction appeared in the literature as early as 1904. The author regards it as surprising, therefore, that the use of special rules has not been more extensive in chemical and process engineering work, since the equations used in heat transfer and fluid flow are quite adapted to such rules. Special single-purpose slide rules designed to solve chemical engineering equations are valuable when repetitive computations must be made, especially by mathematically unskilled persons. The author describes three types of

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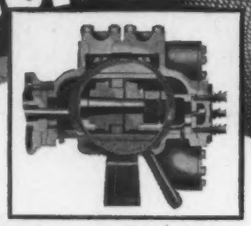

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equations that can be set up on rules, showing in detail how each type is handled. Although mentioning that suitable blanks for special rules can be purchased, he shows how blanks can easily be constructed from cardboard, wood, or other materials. Rules are illustrated for the solution of water heating problem, for solving the Dittus-Boelter equation for liquid heating, for liquid cooling problems, and for calculation of the radiation losses from pipes. A bibliography of 8 references pertaining to the subject is included.

Products: Properties and Utilization

Behavior of Turbine Oils Containing Antioxidants, M. D. BAKER, *Power* **85** (1941) pp. 314-17.

It has been found that antioxidants frequently cause formation of Fe_2O_3 and of dense, hard, and of high abrasive crystals of Fe_3O_4 in the presence of less than 0.1% of water. Changes in viscosity, sludge formation, and neutralization number as criteria of deterioration are critically discussed. The need for a test that takes into account residual antioxidant is emphasized. A test for predicting corrosion-inhibiting qualities is described. Curves are given that show the relationship between neutralization number and service hours corresponding to various degrees of refinement with and without antioxidant. In a 50,000-kw. unit, corrosion was prevented in the presence of 3% of water by the addition of 10% of used oil.

Design of Still Heads for Batch Fractionation in Laboratory Columns, A. R. RICHARDS, *Ind. & Eng. Chem.,* Anal. Ed. **14** (1942) pp. 649-52.

The paper is concerned with further refinements in the design of still heads suitable for the control of batch fractionation with laboratory columns. Low-holdup reflux regulators for batch distillation are described in which the product is removed in the vapor phase. Possible designs are discussed with reference to glass models, and detailed designs are given for still heads of general application. Details of heads applied to 25-mm. Stedman packed columns show how these designs can be modified to suit special requirements.

Reid Vapour Pressure of Alcohol Blends, S. J. W. PLEETH, *Jour. Inst. Petr.* **28** (1942) pp. 113-14.

In the standard method for the determination of vapor pressure of gasoline by the Reid method, A.S.T.M. Serial No. D323-32T, certain precautions and modifications are necessary when examining blends containing ethyl alcohol. Obviously the sample cannot be obtained by water displacement, but the second precaution is less obvious, and can easily be overlooked. The standard method states that the air-chamber shall be rinsed with water before use and the temperature of the air within the chamber taken. It has been observed by the author that the amount of water left in the bomb after rinsing is usually sufficient to cause separation of the alcohol blend into two phases: aqueous alcohol and petroleum spirit. The standard correction therefore no longer applies. The author used a dry bomb, secured by rinsing with alcohol or acetone and blowing with air. The correction factor to be applied in this case

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ignores the water-vapor pressure. The author notes that, contrary to the reported experience in America, he has had no trouble with alcohol blends causing vapor lock as compared to gasoline of the same vapor pressure. He notes that it is possible that erroneous vapor pressure measurements may have caused the comparison of fuels that were really not comparable.

An Oil Manometer-Manostat to Control Column Throughput, S. A. HALL AND S. PALKIN, *Ind. & Eng. Chem.,* Anal. Ed. **14** (1942) pp. 652-4.

The authors recite the difficulties involved in controlling the heat input to the still pot by rheostat or Variac alone, especially at low vapor throughput. If the rate is too fast, it will cause flooding; if too slow, it may fail to supply adequate reflux. On the other hand, manostatic control of heat input to the still takes advantage of the relationship of column pressure drop to distillation rate. The manostatic control described in the paper utilizes oil alone as the manostatic liquid. The movement of the meniscus, as a result of pressure variations corresponding to variations in column throughput, actuate a photoelectric relay that controls the heat input to the still pot. The apparatus is described in some detail, and detailed drawings are also given.

Laboratory Pressure Flowmeter, L. J. BRADY AND B. B. CORSON, *Ind. & Eng. Chem.,* Anal. Ed. **14** (1942) pp. 656-7.

No satisfactory flowmeter, capable of measuring low gas rates under pressure, has been previously available. Heavy glass flowmeters have been used, but this practice is not to be recommended. The authors have developed a metal flowmeter capable of measuring gas rates as low as 500 cc. per hour at normal temperature and pressure. The instrument described in the paper was designed for a maximum working pressure of 2000 pounds per square inch, but the instrument can be designed for much higher pressures. The apparatus is described, and detailed drawings of the essential parts are included in the article.

Oxidation Characteristics of Lubricating Oils, G. H. VON FUCHS AND H. DIAMOND, *Ind. & Eng. Chem.* **34** (1942) pp. 927-37.

The introduction of solvent extraction as a refining process has improved the viscosity index and color of oils and reduced their tendency to precipitate sludge, but it has also been found that an excessively refined oil containing virtually no aromatics is prone to exidize rapidly and to form soluble oxidation products. Considerable concern has therefore arisen over the possibility of overextraction in current practice, and it has been realized that less thorough refining to some intermediate aromaticity may yield a product of greater stability. The oxygen absorption measurement was chosen by the investigators since it can be performed with precision, and is probably the best single criterion of total deterioration. Analysis of rate curves obtained by measurement of oxygen absorption has elucidated the effect of basic composition, methods of processing, and addition agents on the stability of oils. Saturated hydrocarbons

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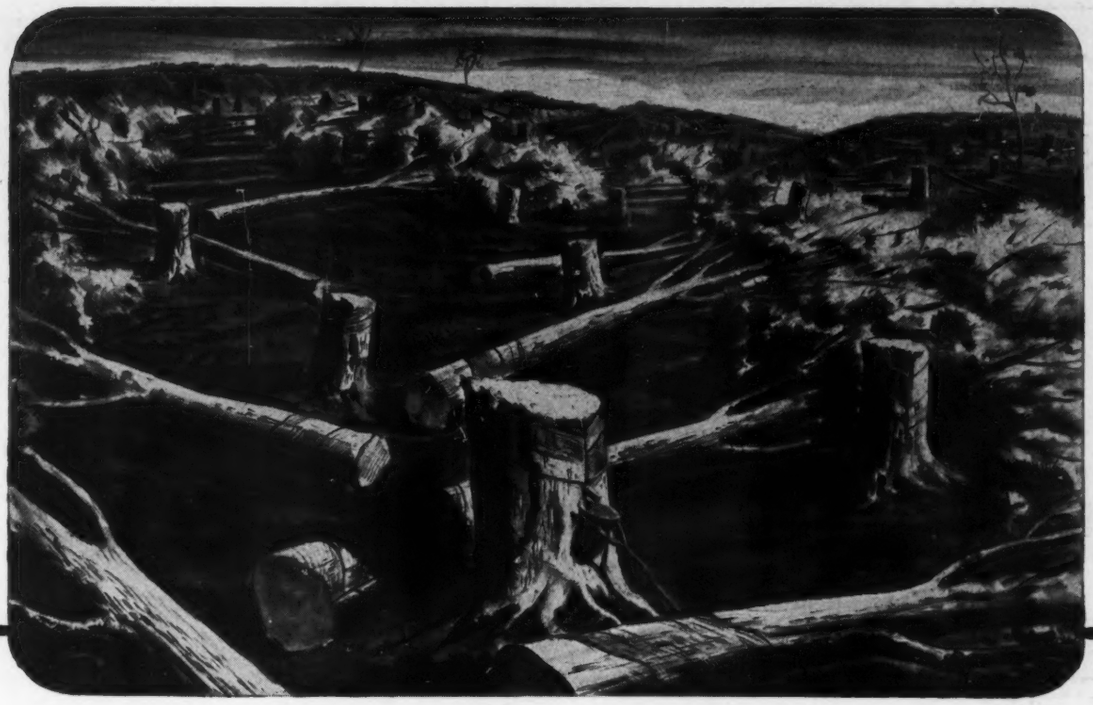
have a tendency to rapid autocatalytic oxidation whereas aromatic compounds act as antioxidants by a mechanism of autoretardation. The results of the oxidation of an oil depends upon the balance between these opposing effects at the reaction temperature. Under given conditions of temperature and metal catalysis, maximum stability is observed at an intermediate or optimum content of aromatic hydrocarbons. The phenomenon of autoretardation is to be distinguished from conventional inhibitor action. Two neutral oils were compared, one a straight distilled oil, and the other a blend of neutral and bright stock. The blend is much the more stable, showing the value of the aromatic components in bright stock.

Viscosity Determination of Polymer Solutions, D. W. YOUNG AND E. H. MCARDLE, *Ind. & Eng. Chem.,* Anal. Ed. 14 (1942) pp. 639-40.

In connection with recent work requiring the rapid and precise determination of polymer solution viscosities, the required accuracy was found obtainable with the Gardner-Holdt rising air bubble viscometer. A new set of bubble tubes extends the Gardner-Holdt series to viscosities of 1000 poises, and thus adapts this rapid method to the measurement of viscosities of high polymers in volatile solvents. The eleven tubes in the set are numbered from ½ to 10, and cover the range from 50 to 1000 poises in steps of 100. To minimize the effect of temperature, each tube was filled with a mixture of a 105 viscosity-index lubricating oil and a polybutene of 12,000 molecular weight. The diameter of the tubes used was double that of the regular Gardner-Holdt series, or 21.3 mm. The length was the same as that of the regular tubes. These dimensions make for ease in filling, and save 80 percent of the measuring time.

Photoelectric Color, I. M. DILLER, R. J. DE GRAY AND J. W. WILSON, JR., *Ind. & Eng. Chem.,* Anal. Ed. **14** (1942) pp. 607-14.

Methods for the measurement and specifications of the color of petroleum products that are in current use are briefly discussed. All are subjective and dependent on the observer, and to a greater or lesser extent on the spectral selectivity of his eye at the time of observation. The use of a photoelectric colorimeter has the potentiality of eliminating the effects of the subjective color response of individual observers or their equivalents. Photoelectric color is a new system for the measurement of the color of lubricating oils. The color is measured directly in technologically significant terms. Only two readings are required: brilliance and characterization of the hur. The system uses a photoelectric colorimeter, designed for accuracy and easy standardization for the measurement of oil colors. The colorimeter has a continuous scale from 1 to 100 for the definition of the intensity of such colors. Deviation of hue of petroleum color from normal is given directly in magnitude and direction. The color definition is independent of the visual response of the operator and of the particular instrument. International Commission on Illumination data can be calculated from photoelectric color, if desired. However, this is rarely required in petroleum



Their roots are sprouting SYNTHETIC RUBBER 10,000 miles away

Thousands of rubber trees have been destroyed in the Far East; it will take years to regrow them. Japan can't hold the rubber groves and the huge raw rubber stocks she has seized, so she probably will destroy them. These dark clouds have a silver lining in synthetic rubbers —made wholly in America, totally by American labor, and serving all America better than tree rubber ever did.

Hycar synthetic rubbers were being produced long before Pearl Harbor. But the war, shutting off the supply of crude rubber, was a stimulus that is bringing astonishing results in chemical research and production of Hycar synthetic rubbers that are vastly superior to tree rubber.

Of course, rubber stocks must be zealously conserved. The needs of the United Nations are tremendous. They get first call on every existing scrap of rubber and on every pound of synthetic rubber produced.

Hycar laboratories are ceaselessly exploring, testing, and developing new formulas and processes. Hycar synthetic rubbers are being manufactured that have marked superiorities over tree rubber and many plastic products. Some of these advantages are better tensile strength and electrical properties; greater resistance to age and harmful effects of oxygen, sunlight and heat.

Certain Hycar compounds, though light in weight and impervious to oil, withstand severe flexing—a combination particularly valuable in bombers and fighting planes. Other Hycar types have unusual resistance to abrasion, a property highly desirable in tires and tank tracks.

Hycar is a raw material furnished to manufacturers of finished rubber products. Your rubber supplier can explain Hycar's advantages. If you are producing a war essential, our chemists and engineers will be glad to cooperate and help on rubber problems. HYCAR CHEMICAL COMPANY, Akron, Ohio.

Built to Beat the Elements that Destroy

Hycar, the synthetic rubber that's made from oil, can be compounded to give you greatest resistance to the combination of oil, heat, and abrasion, highly destructive to most resilient materials. This means that pump piston rings, hose lining, gaskets, all types of seals, and many other important maintenance articles last longer with less time and cost spent on replacement, when you specify they be made of Hycar.

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technology. Photoelectric color can be correlated with the Union system. The method is easily learned and its standardization is based on colored solutions that are reproducible, easily prepared, and sensitive.

Standardization of Mixed Aniline Point and a Critical Examination of Aniline-Point Determination, N. W. GILLAM, *Australian Chem. Inst. J. & Proc.* **9** (1942) pp. 77-88.

The meaning and value of the mixed aniline point test used for solvents high in aromatics was investigated. A standard blend of heptane and methylcyclohexane is suggested. The mixed aniline point is located above the mean of those of the components since the rate of depression of aniline point increases with the content of aromatic compound in the blend. Solvents with aromatic compounds in the same molecular-weight range have the same depressing effect on the aniline point, but aromatic compounds of higher molecular weight have a less effect. In general, increase of molecular weight results in a higher aniline point. Non-aromatic solvents have similar values for the aniline point and the critical solution temperature; the values diverging widely as the content of aromatic compounds increases. The lower layer that separates at temperatures below the aniline point consists of a solution of aniline and hydrocarbons, mainly aromatic. As the result of this, it is possible to determine the aniline points below —5°, the crystallization temperature of pure aniline. The lower limit is the temperature at which the aniline-hydrocarbon imxture will crystallize; this is usually —20° to —30° C.

Furfural Restricted In Rubber Program

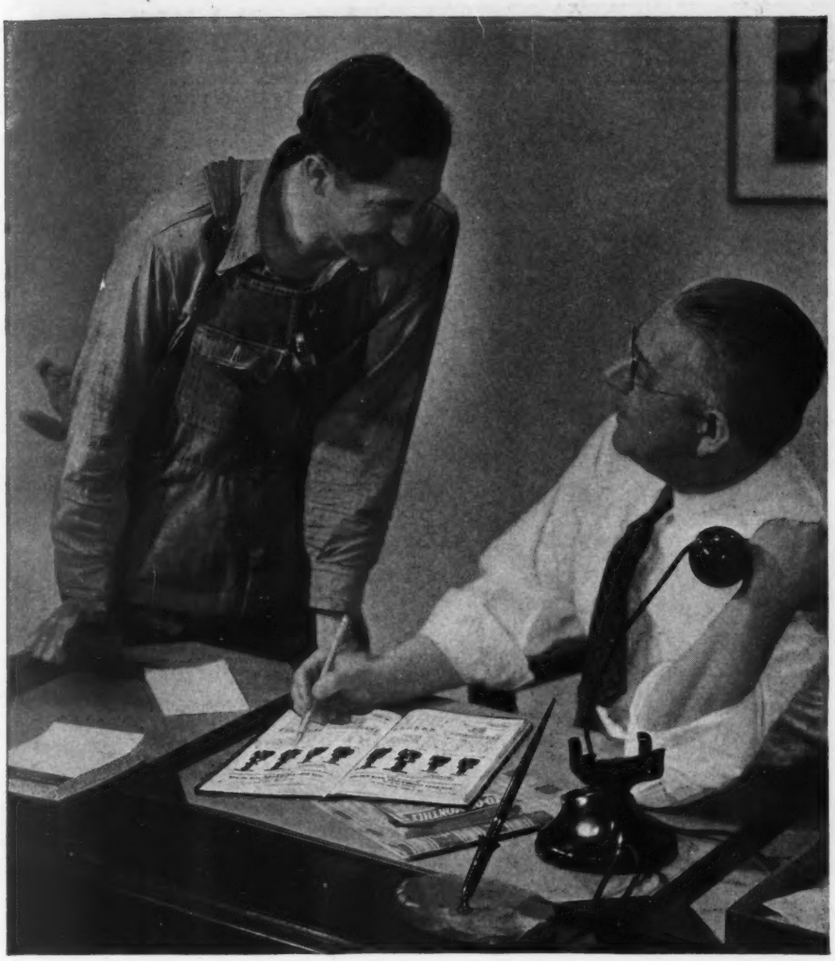
Because of its anticipated use in butadiene production, furfural has been placed under restrictions by the War Production Board. Its delivery or acceptance after October 1 was left to the authorization of the director general for operations.

The order gave this explanation:

"Supply of raw materials from which furfural is made is almost unlimited, corn cobs and oat hulls being the products of a vast number of American farms. Plants to decompose these farm by-products are the bottleneck. The one present plant is turning out furfural at a rate about 25 percent in excess of 1942 requirements, but 1943 requirements will be about five times as great as in 1942. Excess production this year is being accumulated to fill requirements of new butadiene plants after the first quarter of 1943. Furfural required for butadiene alone in 1943 is over three times total consumption for all purposes in 1942.

"To meet the synthetic rubber program, new furfural production facilities capable of producing 24,000,000 pounds a year are being built by Defense Plant Corporation, and will be in operation by April 1, 1943. The new plant, plus present facilities, will provide all anticipated needs for the synthetic rubber program.

"Allocation and end-use control are necessary now because the heavy drain on furfural will come in the next eight months, before new facilities are completed."



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". . . For one thing, every Kennedy Valve in the plant is giving top notch service. We have had some for over 15 years, and they still open easily and close tightly . . . never had a minute's trouble with them. Then again, did you ever look closely at a Kennedy Valve, Well, I have, and I never saw huskier designs, finer metal and cleaner machining. We were just looking over the new Kennedy Catalog, saw exactly the kind of valves we should have in that new plant we're building." The new Kennedy Catalog describes the entire line of bronze and iron body valves of all standard types, also malleable iron, bronze and cast iron pipe fittings. Write for your copy.

THE KENNEDY VALVE MFG. CO.
ELMIRA • NEW YORK

KENNEDY *valves . . . pipe fittings . . . fire hydrants*

NEW EQUIPMENT FOR THE MODERN PLANT

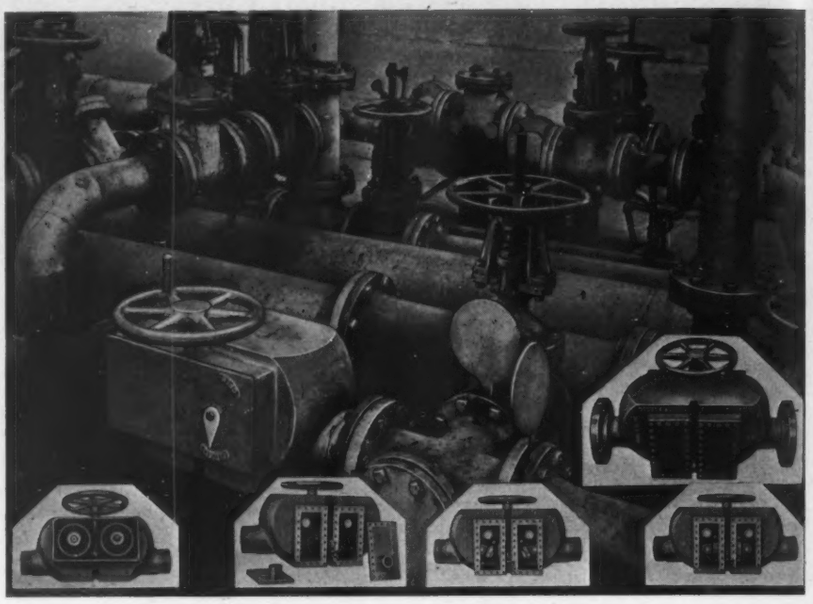
Double-Seal Valve

HAMER OIL COOL COMPANY

Hamer Oil Tool Company, 2919 Gardenia Avenue, Long Beach, California, has added a double-seal-partition valve to its products, for use in refining plants, gasoline plants and other pipe-line applications. It is designed to effect permanent shut-off under pressure with one-man operation in such installations where two gate valves with slip blank blinds are commonly used.

The Hamer double-seal-partition valve consists of a single body containing two opposed valve members which close against seats situated in a central partition. Both valve members are synchronized and raised or seated simultaneously through worm gearing operated by a single hand wheel. The operating gears are sealed in a compartment separated from the valve chamber and are packed in grease. The gearing permits quick, easy opening of the valve under pressure and also insures tight contact of the valves and seats when closed. An external indicator shows whether the valve is open or closed. A small bleeder drains the space in the partition between the valve seats to provide a positive check of the shut-off when the valve is closed.

Advantages claimed for the valve are: That is can be installed in existing hook-ups, releasing the two gate valves and slip blank for service elsewhere; that in new installations, this single unit streamlines the manifold, conserving space and reducing the amount of new equipment needed. In both cases, this valve eliminates all time and labor required in blinding lines and avoids the waste and fire hazards caused by spilling fluid. Maintenance costs and line shut-down time are reduced to the minimum, and shop repair is eliminated, because new valve members and seats can be installed while the valve is in the line. The valve members are designed for a double sealing action, having both metal-to-metal contact with the ground surfaces of the seats, and neoprene squeeze-tight pressure seals. The valve members swing to and away from the seats, eliminating "wire-draw."



Hamer Double Seal Partition Valve

As this valve is operated by one hand wheel which closes both valve members equally and at the same time, the possibility of one valve being left partly open is avoided.

The fluid passage through the valve is a straight-through, oversize round opening, providing sufficient clearance for all line-cleaning devices such as spinners, scrapers, swabs, etc. The valve may be used in any position desired, can be operated by remote control such as extension rods or electric motor, and can be used at temperatures from below 0 to as high as 850° F.

Electronic Voltmeter

GENERAL ELECTRIC COMPANY

GE Voltmeter

General Electric Company, Schenectady, New York, has announced a new electronic crest voltmeter designed to measure ignition voltages of internal combustion engines; surge voltages caused by corona and surface discharges in the insulation on such electric equipment as motors, generators, and cables; and other repeated-impulse voltages up to 30,000 volts.

The instrument, weighing only 23 pounds, fills the need for a portable crest voltmeter for both laboratory and production testing. It is suitable for field measurement, such as trouble shooting and the determination of actual operating conditions, and can also

270 POUNDS TEARS THE DIRT AWAY

...three times the cutting power of fire hose pressures...

Cleaning faster than any other jet method, the Sellers Hi-Pressure Cleaning Jet tears heavy dirt and grease away with a force up to 270 pounds at 180° temperature. The hot water and the solvent soften the dirt; the high pressure tears it away. Sellers' units utilize steam at pressures from 50 to 125 pounds and unheated water at any pressure over 15 pounds. For more information about these time and money saving cleaning jets, write today for a catalog and prices.

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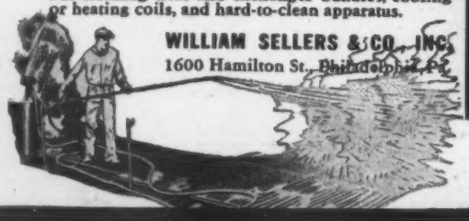

Sellers HI-PRESSURE CLEANING JET

Information supplied by "Petroleum Refiner"

Wartime design is leading to new plants with a minimum of metal—to produce at favorable costs.

In the old days when materials were plentiful and fairly low in cost, rule-of-thumb calculations to set the size of piping or the height and diameter of a fractionating tower did well enough but often they were wasteful.

Design heat exchangers with high heat transfer coefficients; it means less heating surface required, less metal, lower investment. An exchanger with a mean temperature difference of 80° F. and a transfer coefficient of 50 B.t.u./ Hr./Sq. Ft./° F. requires 1250 square feet of surface for a duty of 5,000,000 B.t.u. per hour. A better designed exchanger with a transfer coefficient of 55 will perform the same work with 100 square feet less of surface.

Many companies are reviewing factors of safety used in design of towers. In the light of latest engineering information they may be needlessly high. If a 4-foot diameter tower 40 feet high can be built of steel 1⅛ inch thick instead of 1¼ inches, the saving in steel will be about 1.7 tons.

CLIMAX FURNISHES AUTHORITATIVE ENGINEERING DATA ON MOLYBDENUM APPLICATIONS.
MOLYBDIC OXIDE—BRIQUETTED OR CANNED • FERROMOLYBDENUM • "CALCIUM MOLYBDATE"

Climax Molybdenum Company
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MOLY

be used for testing aircraft engines in flight.

The crest voltmeter can be used in areas where no electric power is available, since it has a self-contained battery power supply. It can be moved readily to any location for testing purposes—a valuable feature when the equipment to be tested is too large to be moved conveniently.

The voltmeter is equipped with an aircraft-instrument movement to provide resistance to vibration. It can be supplied marked and calibrated for any of the following scale ranges: 0-10,000 volts; 0-20,000 volts; 0-30,000 volts.

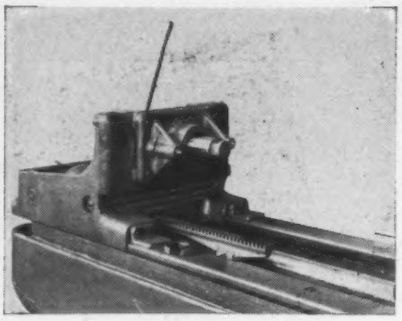
Threading Machine

LANDIS MACHINE COMPANY

The Landis Machine Company, Waynesboro, Pennsylvania, manufacturers of thread cutting machines, die heads, collapsible taps, etc., have recently developed a special work-holding fixture for use with its Land-Maco machine for threading vital components required in the munitions industries. This special work-holding fixture provides a means for accurately and rigidly supporting the work piece during the threading operation.

The fixtures provide a work-aligning arbor on which the work is retained by a collar which fits a square, milled close to the end of the arbor. A lever-operated cam arrangement at the rear end of the arbor provides a means for drawing and locking the work piece onto two driving and locating pins.

The special work-holding fixture, as described is fastened to a face plate



Landis Threading Machine

which bolts to the machine carriage in place of the conventional carriage front or vise. The fixture has both horizontal and vertical adjustment on the carriage to assure accurate and permanent alignment of the work piece with the center of rotation of the threading unit. This fixture was designed with a view of holding to within extremely close tolerances for thread concentricity, and to assure maximum production by eliminating the time otherwise required if the work piece were gripped in the conventional vise.

Extinguisher

O. H. ADAMS COMPANY

O. H. Adams Company, Milwaukee, announces a new fire and war gas extinguisher, recommended by the manufacturers as an effective fire extingisher and as a decontaminator for the three major war gases.

The new product is also recommended for combating automotive, airplane, industrial and marine fires, and is effective for household and factory fires. The product is non-injurious and lasts indefinitely.

Transformer Cooler

ALLIS-CHALMERS MANUFACTURING COMPANY

Allis-Chalmers Manufacturing Company, Milwaukee, has designed a system of forced-oil cooling for transformers, known as the "Electro-Cooler."

The forced-oil system of cooling transformers is made highly practical because the unit is built compact, factory-assembled and factory-tested at high pressure to minimize the possibility of future maintenance. If the transformer has radiator valves, the unit can be removed without draining the transformer oil, and parts can be replaced without delay in transformer operation.

It consists of a radiator-type cooler and a special pump with motor enclosed. These are connected by piping to the standard radiator valves at the sides of the transformer. No stuffing boxes are required in the special pump, and the motor is self-cooled and self-lubricated.

Because the new cooling unit is relatively small, usually more than one is required, the number depending upon the size of the transformer. Greater reliability can be expected from the multiple units, since operation of one is not dependent upon the other.

It can not only be built into new transformers, but can be readily ap-

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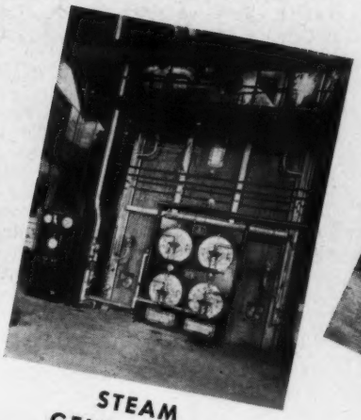
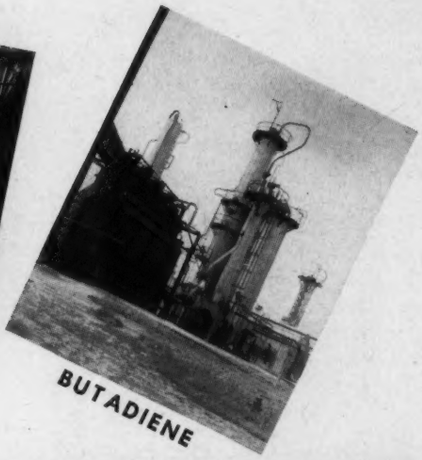


STEAM GENERATION



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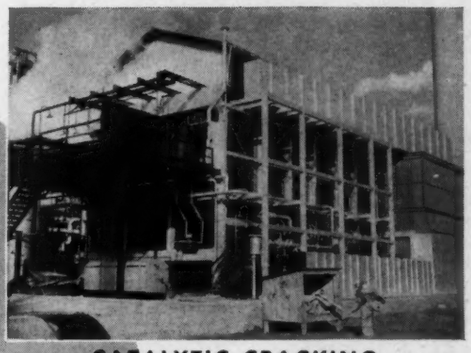
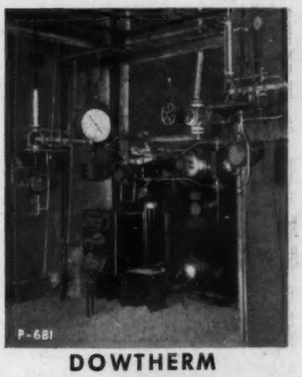
OIL BURNERS GAS BURNERS

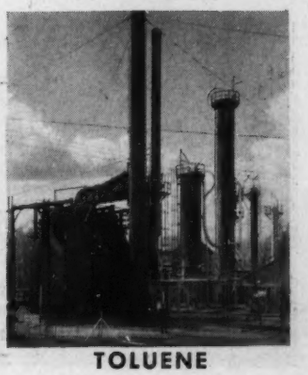
For thirty years the National Airoil Burner Co. has been making Fuel Oil Burners and Gas Burners for a large number of the leading companies in the Petroleum-Chemical Industries. This broad experience has helped meet combustion requirements of these industries for the development and operation of many of the new processes.
Can we be of service to you?



CATALYTIC CRACKING



DOWTHERM



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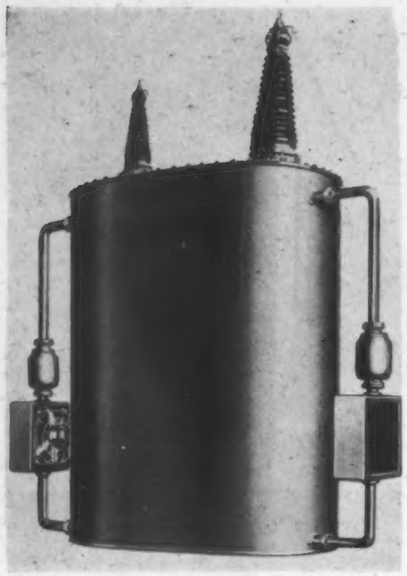


A-C Transformer Cooler

plied to transformers already in service, subject to the recommendations of the transformer manufacturer. If the transformers are equipped with the conventional type radiator valves, installation can be made in three to four hours without even removing the oil in the transformer.

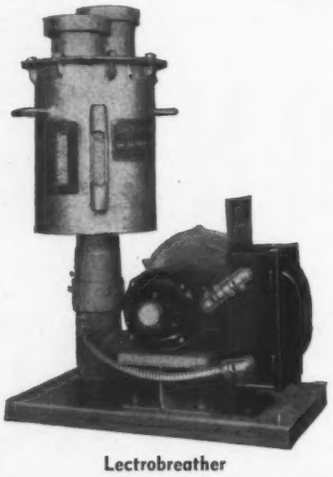
Moisture Removal

LECLECTRODRYER CORPORATION

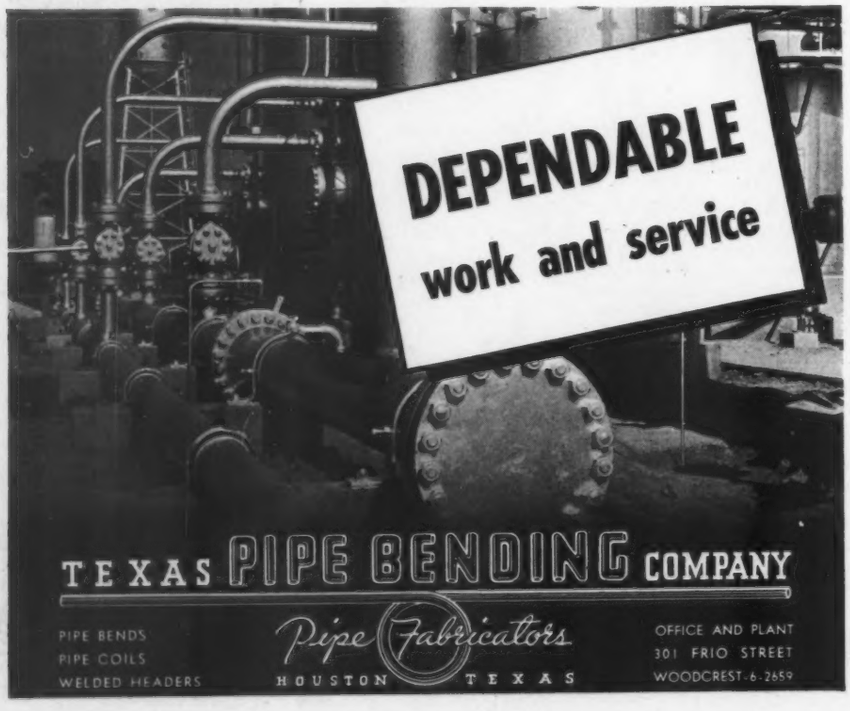
Lectrodryer Corporation, 1070 Thirty-second Street, Pittsburgh, has designed the Lectrobreather for the removal of moisture from atmosphere when installed on oil and chemical tanks.

Lectrobreathers permit only dry air to enter the tank when it is emptied or when air enters due to temperature drops. Air leaving the tank, being thoroughly dry, has a partial reactivating effect which makes possible long periods between reactivations. They are mounted either directly on the tank or piped to it and are equipped with a color indicator for determining when reactivation is needed or when it is complete. Where lectrobreathers are required for several tanks, the standard practice is to use one lectrobreather on each tank and a central reactivator for all breathers. The reactivators are built for electric operation as standard for all units or for steam operation on the two larger units. Special lectrobreathers are available for use on transformers or other equipment where atmospheric moisture is harmful.

Lectrobreathers use activated aluminas, which are dependable, time-tested adsorbents. They operate on the same principle as lectrodryer equipment which is successfully used in many industries for drying compressed air, gases and for maintaining lower than normal relative humidities in rooms. Complete information will be furnished on request.



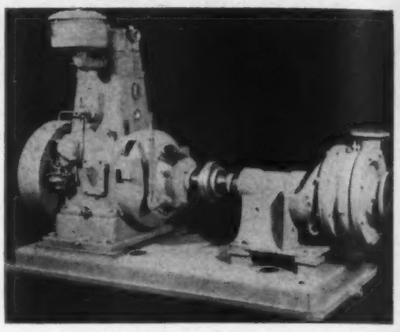
Lectrobreather



Pump Assembly

ALLIS-CHALMERS AND WITTE ENGINE WORKS

New in design and new in construction Allis-Chalmers pumps are providing dependable pumping performance which is proving a real help in enabling industry to meet most exacting wartime requirements.



Allis-Chalmers-Witte Pump

These compact, s t u r d i l y - mounted pump-and-power units are highly popular, not only with industrial users but also with the government for which they are also being manufactured.

This model of Allis-Chalmers pump is powered with Witte Diesel Engines manufactured by Witte Engine Works of Kansas City, Missouri, who have joined hands with many pump manufacturers to produce combination pump-and-power units to serve America's war effort.

Orifice Computer

SONNEY ORIFICE COMPUTER

The Sonney Orifice Computer, Central Avenue Extension, Oil City, Pennsylvania, has announced a new device to facilitate orifice meter computations. The computer is made of transparent celluloid discs on white opaque back in two designs and sizes and is exceptionally useful for quick determination of:

1. Rate of delivery of gas through an orifice meter;
2. Size of orifice to install in a meter;
3. Differential to maintain to deliver a desired rate of gas;
4. Pressure to maintain to deliver a desired rate of gas, and
5. Open flow of a well when using the orifice open flow tester.

No coefficient for the orifice is necessary in order to use this instrument but if the coefficient or gas characteristics are known, all corrections are provided on the larger size computer to permit accurate computation.

The pocket size instrument is about 3 inches by 5 inches, rectangular shape, and is designed primarily for orifice meter operators and field men. The utility size is circular shape, about 4½-inch diameter, and is suitable for office, shop or field use.

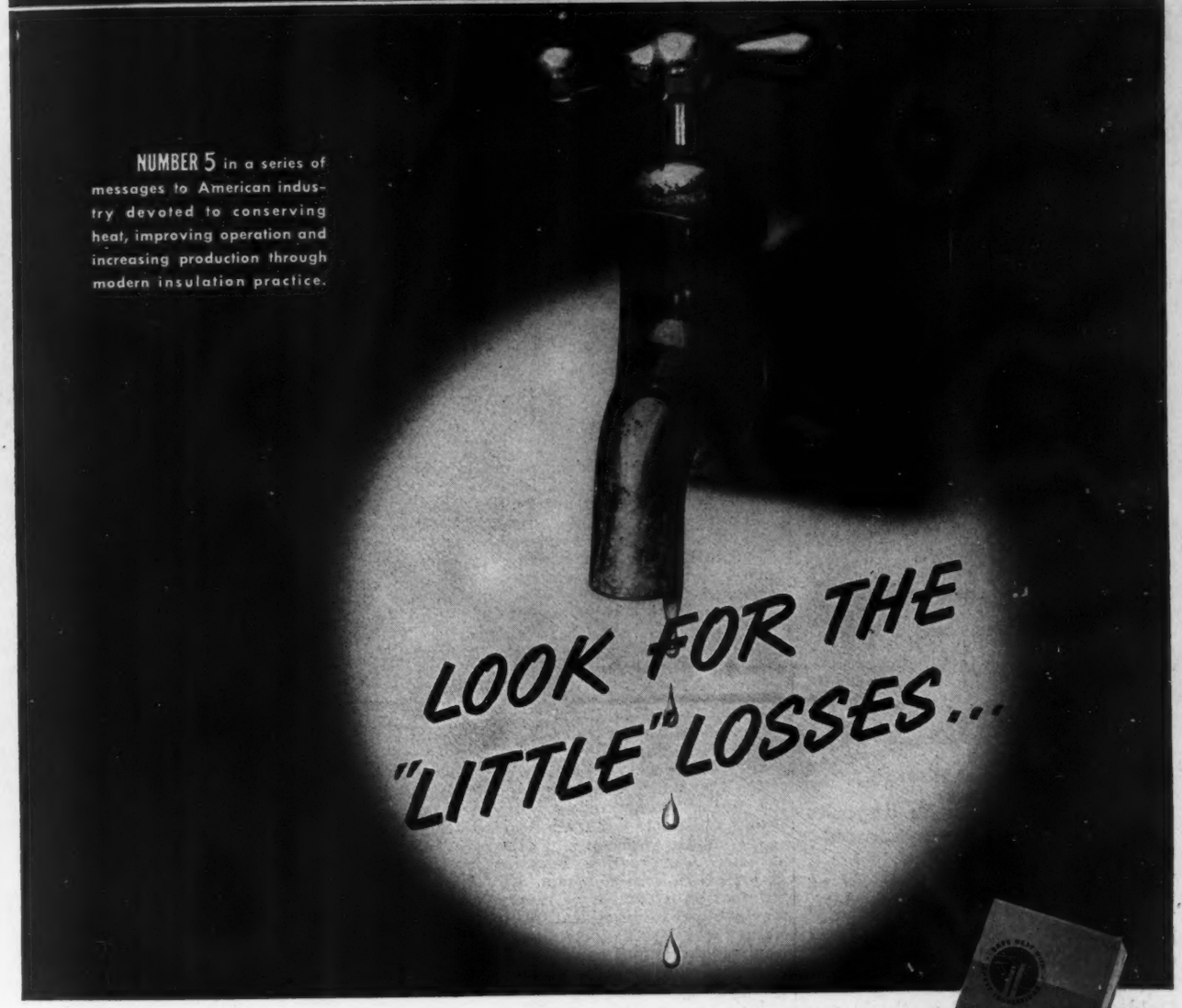
Water-Test Sets

W. H. AND L. D. BETZ

W. H. & L. D. Betz, Gillingham and Worth Street, Frankfort, Philadelphia, has designed a series of water-test sets, which include the necessary chemicals and apparatus for determining hardness, alkalinities, chlorides, phosphates and sulfites in water, when any two, three or four of these tests are required.

A special cabinet designed for use on table or wall is provided. All chemicals

GETTING THE *MOST* FROM YOUR THERMAL INSULATIONS...


NUMBER 5 in a series of messages to American industry devoted to conserving heat, improving operation and increasing production through modern insulation practice.
LOOK FOR THE "LITTLE" LOSSES...

Like water lost from a leaking tap, the heat lost from an unprotected flange, valve or small pipe line may seem comparatively insignificant . . . but many of the few make much, and these steady small losses can quickly add to incredible totals.

With operations under war demands proceeding at two and three times normal capacity, it is necessary that every possible pound of steam be generated, every last bit of heat conserved. The insulations on your boilers, piping and equipment should be maintained in good service condition, and all exposed lines, flanges and fittings should be adequately covered with an efficient, time-tested material . . . such as Ehret's 85% Magnesia.

★ EHRET'S 85% Magnesia and many other Ehret heat insulating materials are fully treated, both as to selection and application in the 176-page Ehret Heat Insulation Handbook. It will be furnished, without obligation, to those interested in getting the most from their thermal insulations. Write today for your copy of Handbook F210.

EHRET MAGNESIA MANUFACTURING CO.
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YOU CAN
DO THESE 8 JOBS
EASIER and FASTER
the low-cost Oakite way!

1. De-scaling Diesel and gas engine cooling systems
2. Cleaning tank car interiors
3. Salvaging valves and fittings
4. Cleaning absorption towers
5. Reconditioning oil drums
6. Cleaning heat exchangers
7. Washing pump station floors
8. Removing lime scale deposits from refrigerating equipment

When you handle each ONE or ALL of these maintenance jobs the Oakite way, you will find you can do the work EASIER . . . also in LESS TIME! This is because Oakite materials and methods are specially designed for a specific type of work. As a result, you conserve valuable man-hours, reduce equipment down-time, increase operating efficiency, and save money!

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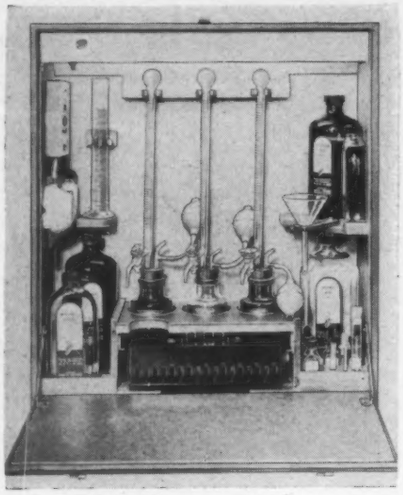


Betz Water-Test Set

and apparatus are contained in the cabinet, held in a secure position and ready for instant use. A portion of the opened cabinet door forms a convenient acid-resistant laboratory work table, and a fluorescent light provides correct illumination for the tests. The protection afforded by the cabinet minimizes breakage and eliminates errors caused by dust or dirt. All "A" Series test sets are ready for immediate shipment.

Carbo Petro-Non-Solv

CARBOZITE CORPORATION

Carbozite Corporation, First National Bank Building, Pittsburgh, Pennsylvania, has developed Carbo Petro-Non-Solv to answer demands for a coating to protect concrete or wood storage tanks against infiltration into their contents by gasoline and oil.

This new coating contains no oil, therefore it will not saponify when in contact with cement or mortar. One of the product's unique features is its absolute inertness to petroleum, coal tar and manufactured solvents, organic and inorganic oils and fatty acids.

Carbo Petro-Non-Solv will dry hard within two or three hours. Two or three applications are recommended, depending upon the porosity of the surface to which it is applied. Two coats are usually sufficient on steel or wood. Three may be necessary on concrete surfaces. The first coat will cover approximately 150 square feet per gallon, while on subsequent coats a gallon will cover 200 square feet.

Compressor

CLARK BROS. COMPANY

Clark Bros. Company, Olean, New York, has announced development of a Clark "Angle" compressor driven by steam, and built in units up to 4000 horsepower. One of the new 8-cylinder 4000-horsepower steam-driven units equals in capacity a battery of 10 of the 4-cylinder 400-horsepower gas-driven "Angles."

The war has greatly augmented industry's demand for compressor capacity, and Clark "Angles," both in the gas-driven models up to 1000-horsepower and the steam-driven up to 4000-horsepower are in constant demand for many new services, the company says.

Among the purposes for which Clark "Angles" are being installed are natural-gasoline recovery, high-octane gasoline manufacture, gas recycling, distillate recovery, gas boosting, oil refining, pressure maintenance, gas liquefaction, gas distribution, manufacture of synthetic ammonia, synthetic alcohol, toluene, oxygene, helium, magnesium, carbon dioxide, and other gases and chemicals, synthetic rubber manufacture, water flooding, generator drive, refrigeration, air compression for glass plants, rock quarries, mines, foundries, machine shops, tank, plane, aluminum, and steel plants.

The steady growth in industry's need for compressor plants of large capacity has led Clark to constantly study the problem of developing larger units in this field, it was explained.

Thumb Spray

PYRENE MANUFACTURING COMPANY

Pyrene Manufacturing Company, 560 Belmont Avenue, Newark, New Jersey, has designed a thumb spray nozzle attachment, so standard fire extinguishers can be converted to possible emergency needs of extinguishing magnesium bombs and other fires. It clamps over the hose of any standard soda-acid, foam, gas-cartridge or pump-tank extinguisher.

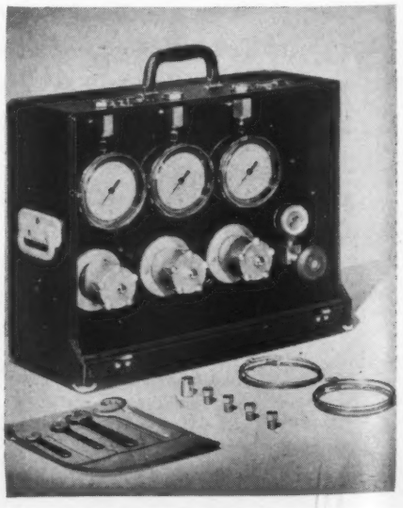
Thus the normally solid stream is converted into a spray by pressure of the thumb. Since this takes places after the liquid leaves the nozzle the extinguisher is not affected.

Gauge Tester

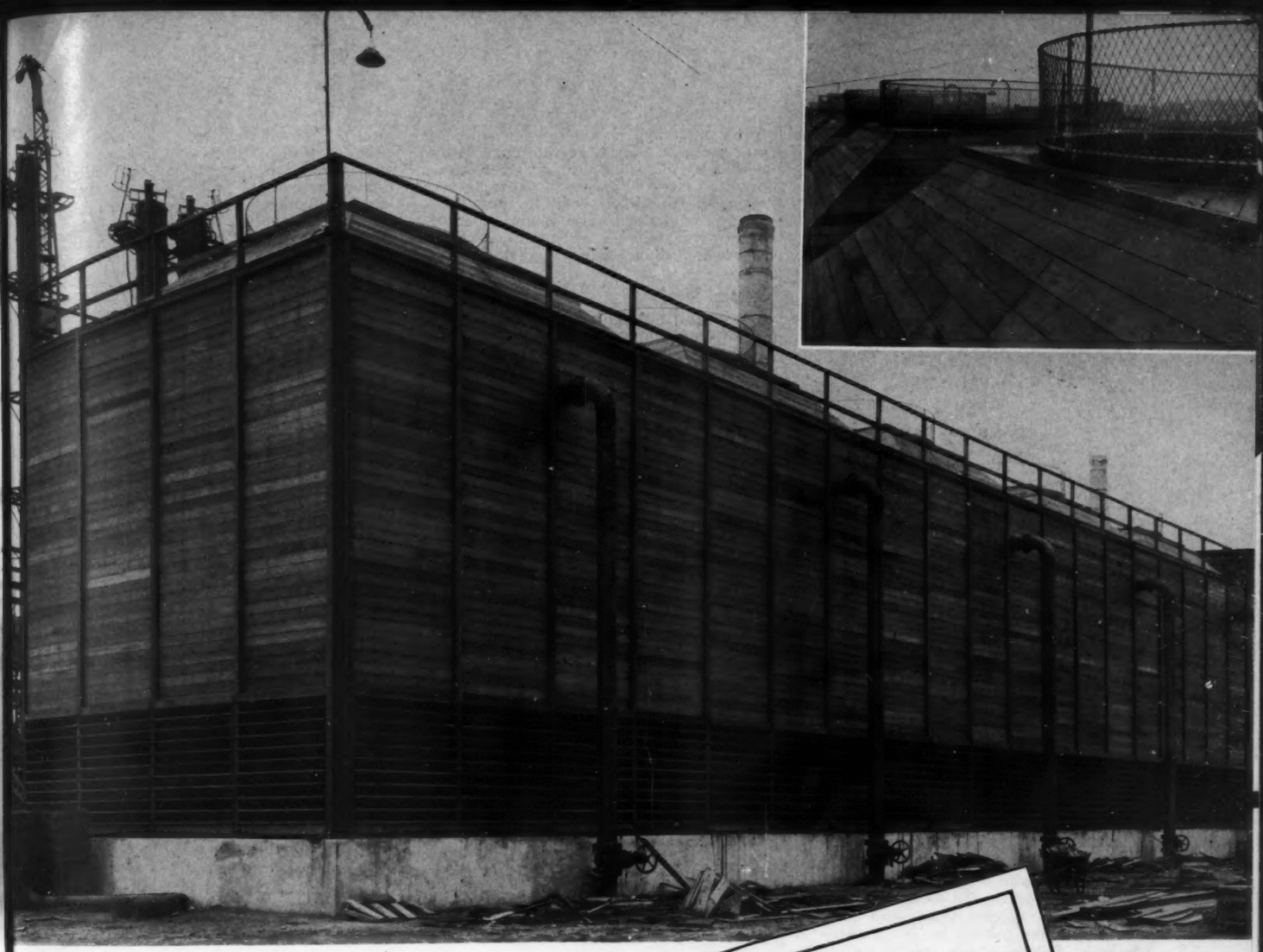
GROVE REGULATOR COMPANY

Grove Regulator Company, Oakland, California, has designed the Grove Gauge Comparator for checking all times of mounted pressure gauges without removing them from mountings and without breaking line connections.

Equipped with three precision laboratory test gauges, accurate to within ¼ of 1 percent of full scale, the Grove Comparator will check various ranges of pressure gauges from 0 to 1000 pounds. Necessary testing pressures are supplied from built-in high-capacity air cylinders, which can be charged and recharged as often as required with any clean, dry gas, air or oxygen. The extremely fine degree of pressure control is made possible by three Grove Pressure Loaders mounted below each



Grove Gauge Tester



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WATER COOLING EQUIPMENT CORPORATION

ST. LOUIS, MISSOURI

This cooling tower is one of a group of similar units installed at one of America's largest refineries. It is designed for service in connection with equipment for producing aviation gasoline.

Water Cooling Equipment Corporation cooling towers are cooling OVER FIVE HUNDRED MILLION GALLONS of water per day at War Production Plants throughout the country. Their superior engineering design and dependable cooling characteristics assure efficient and uninterrupted production of vital war supplies.

"General Grants"---

THEY'RE TOUGH, FAST AND HARD HITTERS!

Challenged by an aggressive enemy with years of war machine building experience, American engineers, in record time, designed, tested and built the famed "General Grant" tanks. Heavily gunned, tough and fast in the field, these steel monsters can out-fight, out-shoot and outmaneuver anything the Axis powers have yet rolled out.

But it takes water to build tanks—water for the men who work in the plants—for those who produce the steel for those who operate and service them—and for millions of other people in the Service of Supply. Before plants could be built, armies trained and munitions made, there had to be an abundance of water. Upon the old, reliable and capable shoulders of the Layne Organization fell much of the task of producing that water. Layne swung into action and in record time, built deep well water systems by the hundreds, thus making possible unprecedented war and production programs.

Layne's reputation like that of the "General Grant" tanks, has been won on the field of action. Layne wells and pumps are doing an outstanding job—operating day and night, producing millions and millions of gallons of water for almost every phase of America's war effort. For late bulletins, wire or write LAYNE & BOWLER, INC., Memphis, Tenn.

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Layne-Bowler New England Corp...Boston, Mass.
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Layne-Northern Company.....Mishawaka, Ind.
Layne-Louisiana Company.....Lake Charles, La.
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Layne-Northwest Company.....Milwaukee, Wis.
Layne-Ohio Company.....Columbus, Ohio
Layne-Texas Company.....Houston, Texas.
Layne-Western Company.....Kansas City, Mo.
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WORLD'S LARGEST WATER DEVELOPERS

test gauge. The Grove Loader serves as an accurate pressure-reducing valve with built-in automatic relief. Because of its large diaphragm-to-valve-area ratio, it provides positive pound-by-pound controlled and maintaned accuracy of delivery pressures, whether increasing, decreasing or constant.

Plug Valve

HOMESTEAD VALVE MANUFACTURING COMPANY

Homestead Valve Manufacturing Company, Caraopolis, Pennsylvania, has introduced a new line of Lever-Seald plug valves for 150 pounds working pressure. Sizes range from ½-inch to 10-inch in either semi-steel or steel.

Homestead Lever-Seald Valve

Face-to-face dimensions of each valve in the new line are the same as those of the corresponding size of wedge-gate valve. Thus they are instantly interchangeable with wedge-gate valves, without piping changes.

Other features of the new line include Homestead's traditional "quarter-turn" operation, and a powerful leverage to provide positive, extra-easy opening or shut-off under all conditions.

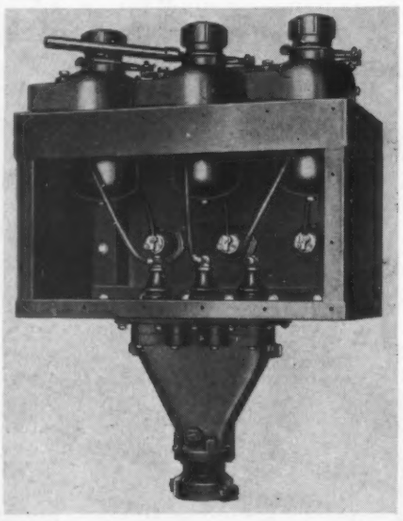
Fuse Cutouts

GENERAL ELECTRIC COMPANY

General Electric Company, Schenectady, New York, has announced a new metal-enclosed assembly for gang-operated oil fuse cutouts for economical short-circuit production and switching.

The new cutout assemblies permit totally metal-enclosed installations, either single- or three-phase. They save installation labor because each unit is factory-assembled with flexible, insulated cable leads ready for connection to either single- or multi-conductor cable. The leads enter the individual cutouts above the oil level, thus preventing loss of oil. Switching requires merely throwing a lever 90 degrees. Fuse carriers can be removed without disturbing the gang-operating mechanism.

The new assemblies can be supplied for wall or direct-to-apparatus mounting, with openings for conduit, cable, or pothead connections.

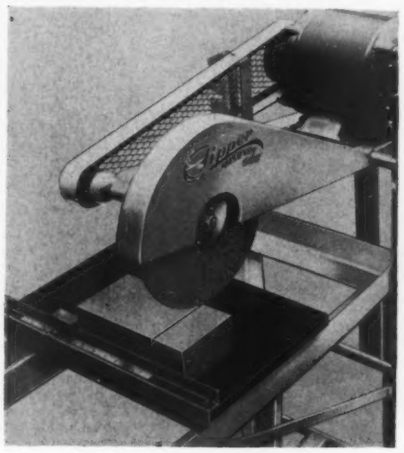


GE Fuse Cutout

Masonry Saw

CLIPPER MANUFACTURING COMPANY

Clipper Manufacturing Company, 4030 Manchester Avenue, St. Louis, has a power-driven saw for shaping brick and masonry materials in furnace-wall and other construction of this type. It can be used in cutting glazed tile, fire brick, clay and concrete products.



Clipper Masonry Saw

Cuttings are automatically discharged to eliminate frictional heat.

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"Rubber", plastics, solvents, high octane gas, aviation lubes, industrial fuel oil, explosives—not to mention common fuels and lubricants . . . through all these, Democracy finds encouragement in oil's amazing contributions to Victory. Planes—warships—trucks—jeeps—motorcycles—guns—today they're all flying, shooting, riding high, wide and Victoryward, sparked by the petroleum industry. ¶ And . . . while a bomb explodes, research is converting the equivalent of its toluol content into a beautiful new upholstering material. While a pilot soars with "perfect" 100 octane gasoline, a new "rich mixture" is about to emerge from the testing laboratory. Thus petro-chemistry hints at developments that stagger the imagination . . . ¶ This vital activity demands expansion because America is on the move . . . to Victory now and Progress later. Ohio Seamless is looking ahead to its role in this expansion. Ostuco Seamless tubing has been "in" on petroleum developments for many years. Now it is keeping pace with rapid-changing steel specifications and alloys and is setting a new pace in seamless tubing developments. Ohio Seamless will be ready also for the *petroleum* industry's future expansion.

THE OHIO SEAMLESS TUBE COMPANY

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You will find the metal protractor a useful, convenient tool, and the SMOOTH-ON Handbook will help you repair plant equipment that you cannot replace because of war-time conditions. Some of the subjects covered:

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☆ BUSINESS NOTES ☆

Westinghouse to Build Synthetic Rubber Turbines

Construction has started by Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania, on three large steam turbine generators to provide power for the synthetic-rubber industry, F. H. Stohr, manager of the company's industry sales department, has announced.

The abundance of high-pressure steam required for the production of butadiene and styrene will enable new chemical plants to generate their own electric power as a by-product. The steam will be used, first to drive the turbine generators and then in the chemical processes.

Installed in Pennsylvania and Indiana chemical plants that will produce the raw materials for Bune S rubber from petroleum and coal by-products, the generators will deliver 115,000 kilowatts.

Part of this electricity will supply the motors and lights in the chemical plants, as well as in the adjacent copolymerization plants in which the chemicals are combined to make rubber.

Construction of the generators constitutes one of the first steps in building a vast new industry in which electric power will play an important part. Power from these and from other generators yet to be ordered will supply the first four large synthetic-rubber plants in this country, scheduled for completion during 1943.

Gisholt Awarded Army-Navy E

Both the award of the Army and Navy and that of the Treasury department went to Gisholt Machine Company, Madison, Wisconsin, because of production efficiencies and purchase of war bonds by employes. It was the first award of this type for a Madison manufacturing company.

Worthington Names Cleveland Manager

R. J. Laidlaw has been named Cleveland district manager of Worthington Pump and Machinery Corporation. He succeeds A. J. Klug, who will devote full time to special work in that area. Laidlaw has been with the Worthington organization since 1919.

Bailey Meter Opens Two More Branches

Bailey Meter Company, Cleveland, has opened two West Coast branch offices, one at Los Angeles, the other at Seattle. L. F. Richardson has been named manager of the Los Angeles office, while H. T. Sawyer will be in charge at Seattle. The two men have been in these territories in the past but had functioned as representatives of the San Francisco branch, which will continue under the management of V. A. Humble, who is West Coast supervisor.

H. T. SAWYER

L. F. RICHARDSON

Rippie to Monsanto Chemical Company

Dr. Charles W. Rippie, formerly petroleum technologist for Solvay Sales Corporation, has joined the Petroleum Chemicals Department of the organic chemical division of Monsanto Chemical Company, St. Louis, where he will handle technical sales work. Dr. Rippie has a broad background in the petroleum field, having served in research, manufacturing and sales capacities with Shell Oil Company and Cities Service Oil Company before going to Solvay.

Kirkpatrick Elected President of Landis Machine

C. N. Kirkpatrick has been elected president of the Landis Machine Company, Waynesboro, Pennsylvania. He will continue to serve as general manager, which he held as vice president.

G. M. Stickell, sales manager, has been promoted to vice president and will continue his duties in charge of sales.

Leeds & Northrup Gets Merit Award

The Army-Navy "E" Production Award was made to Leeds & Northrup Company, 4901 Stenton Avenue, Philadelphia, September 5. C. S. Redding, president, explained that the activities which led to the award consist of maintaining a many-fold increase in production of the regular L&N lines of measuring instruments, telemeters, automatic controls and heat-treating furnaces, and super-imposing on that production the manufacture of a large amount of classified materiel for the armed forces.

Admiral Henry A. Wiley, retired, in

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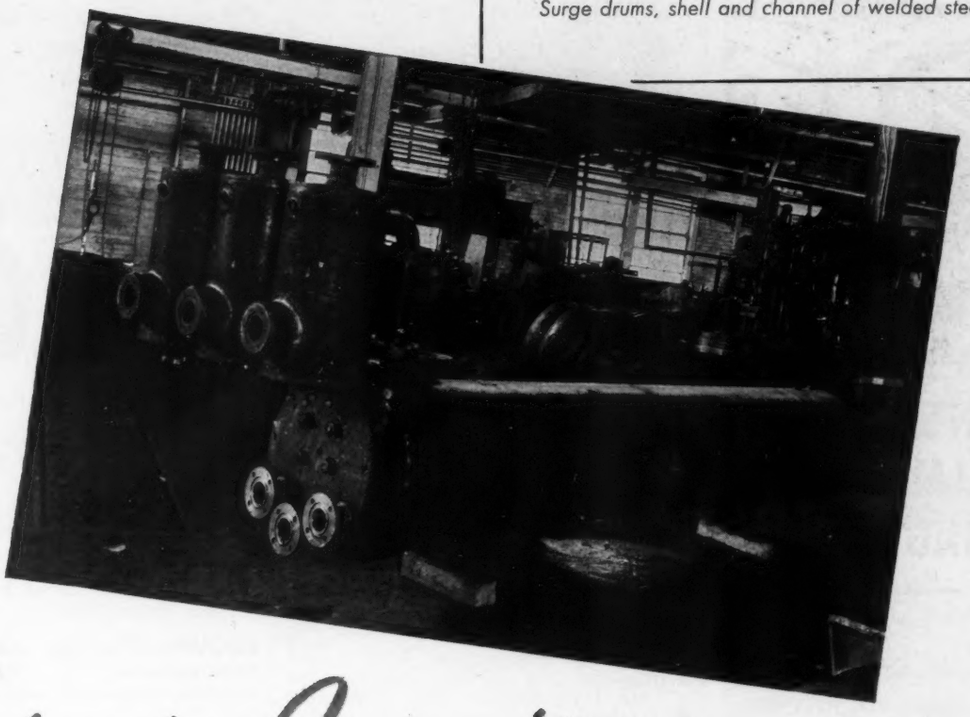
775' of ¾" No. 16 B. W. G. tubing went into this Patterson-Kelley Recirculating Gasoline Cooler. A single shell houses 3 separate circuits. It is furnished with individual surge drums. Shell baffles are of copper. Surge drums, shell and channel of welded steel.



Engineering Ingenuity BY PATTERSON-KELLEY

From the point of view of size and materials required for its construction, this Patterson-Kelley recirculating gasoline cooler isn't what industrial engineers would call a "big" job. But the unique arrangement of its individual surge drums proved to be the *right* answer to the operating conditions it was designed to meet.

You'll like the way Patterson-Kelley engineers approach a problem in the design or construction of a piece of refinery equipment. In the first place, their attitude is that *there is a right answer* to any legitimate problem in engineering—no matter how difficult it may be. In the second place, they give the same careful attention-to-details to a small cooler or condenser that they do to a large interchanger which may require 7,500 square feet of heating surface.

At Patterson-Kelley's East Stroudsburg plant there is no compromise of quality in materials or in workmanship. We are prepared to design and build equipment to meet the most exacting requirements of your operations. Our engineers will be glad to consult with you on your equipment problems—at no cost to you.

PATTERSON-KELLEY *FOR DEPENDABLE ECONOMICAL SERVICE*

EST. 1880

PATTERSON-KELLEY HEAT EXCHANGE ENGINEERS

THE *Patterson-Kelley* CO., INC.

113 WARREN ST., EAST STROUDSBURG, PA.

MANUFACTURERS FOR THE REFINING AND PROCESS INDUSTRIES

making the award, said that the recommendations on which the award was based "could not have been higher." Admiral Wiley praised the cooperation, ingenuity and full use of manpower and materials which the company had displayed.

In addition to Redding, other spokesmen for the company were J. L. Johnson, president of the L&N Employees' Association, and W. F. Smith, president of the L&N Cooperative Association. The speakers urged the importance of continually increased production, and in Smith's words, pledged "Production is going to keep on rising until this war is won."

Maritime Award Given To Kerotest Company

The first Pittsburgh district production award by the United States Maritime Commission was presented to the Kerotest Manufacturing Company, Pittsburgh, recently. Ceremonies were held in the company's newly completed building.

Making the presentation of the award was C. E. Walsh, Jr., chief of the commission's procurement division. The Maritime "M" pennant and victory fleet flag were accepted on behalf of Kerotest employes by E. G. Mueller, president of the company. John Walters, chairman of the Employes Maritime Day Committee, accepted the labor merit pins, given to all workers.

Acting Manager in Chicago Territory

W. G. McFadden has been named acting manager of the Chicago office of Allegheny Ludlum Steel Company. His selection followed the resignation of P. E. Floyd, who is now serving in a capacity with the federal government.

Voelker Promoted by Pittsburgh Steel

Joseph A. Voelker, district manager for Pittsburgh Steel Company in New York, has been named general manager of sales with headquarters at Pittsburgh. W. F. Boore, who has been in the New York office for several years, is acting sales manager in that territory.

Joins Foote Brothers Engineering Staff

Irwin A. Marshall has been added to the contact engineering staff of Foote Bros. Gear and Machine Corporation and will represent the company in the northern Ohio territory with Cleveland as headquarters.

He has been serving industry in that area for the past 12 years as a specialist in power-transmission equipment.

Ohio Injector Given Army-Navy Pennant

Ohio Injector Company has been presented the "E" Pennant of the Army and Navy at ceremonies in the valve plant at Wadsworth, Ohio. The award was the first in the valve industry.

Joins United States Stoneware Company

Herbert D. Schmidt has joined the sales department of United States Stoneware Company, where he will have headquarters in the New York office. He will devote most of his time to the sales of Tygon, a synthetic prod-

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You Save 25% *Over Cost of New Valves*

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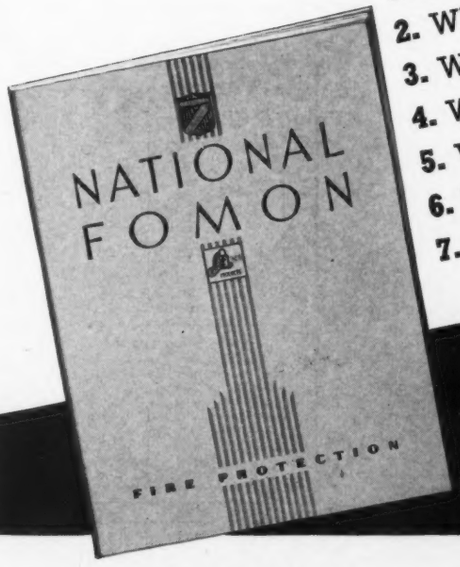

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"MELOIL"

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MELRATH
SUPPLY & GASKET CO., INC.
Tioga & Memphis Sts., Phila., Pa. Est. 1909

uct for tank lining and other industrial uses. Recently he has been with American Hard Rubber Company. He has had 15 years of experience in the chemical equipment industry.

Second Award Made To Foster Wheeler

The Dansville, New York, works of the Foster Wheeler Corporation was given the E award of the Army and Navy in August, giving the company a second award, as the Carteret, New Jersey, plant received the honor in May.

The presentation was followed by presentation of a Minute-Man Flag in recognition of full participation in war-bond purchases at the Dansville plant.

Power Show Moves to Madison Square Garden

The fifteenth Exposition of Power and Mechanical Engineering will be held November 30 to December 4 in Madison Square Garden, New York. The event was planned for Grand Central Palace, which has been converted to military uses.

The exposition is held biennially. Charles F. Roth is manager and headquarters are maintained at 480 Lexington Avenue, New York.

Babcock and Wilcox Given M Award

The Babcock & Wilcox Company has been given the "M" award of the United States War Shipping Administration. Presentation at the Baberton plant was made September 3 by Admiral Emory S. Land, chairman of the Maritime Commission. This award now flies alongside the Navy "E," which was awarded May 11.

Names Changes for Kidde Products

Carbon dioxide fire extinguishers and extinguishing systems manufactured by Walter Kidde & Company and previously known as "Lux," "Luxomatic," "Selex," etc., will henceforth all be labeled "Kidde." Sole exceptions are the "Rich" and "Richaudio" marine detecting systems. In line with wartime conservation of scarce materials, the "Kidde" label is being made of steel instead of brass, and is narrower than the previous "lux" label.

R. A. Chaffe to Army Air Corps

R. A. Chaffe, who was in the engineering department of Clark Bros. Company for four years, has been commissioned a second lieutenant in the Army Air Corps.

He was graduated from Ohio State University in 1938 with a degree in Mechanical Engineering and entered the experimental testing department at Olean, New York. Two years later he become erection engineer in the California and Mid-Continent oil fields and remained in this work until going into military service.

Wheelco Adds Three To Its Sales Staff

Wheelco Instruments Company, Chicago, has added three men to its sales and service organization. C. L. Clark, formerly with Westinghouse Electric & Manufacturing Company, is now in the Cleveland office as sales engineer; Robert N. Miller, who has been with Mercoid Corporation, is the service engineer in the Cleveland office; while Howard B. Jones, recently with McGraw-Hill Publishing Company, is in the Chicago office as a sales and service engineer.

Official of Kimble Glass Company Dies

Harry V. Wallace, vice president and director of sales for Kimble Glass Company, Vineland, New Jersey, died September 15. Following service in the First World War he had sales experience with Socony-Vacuum Oil Company and Owens-Illinois Glass Company before becoming Chicago branch manager of Kimble Glass Company in 1931. He came to the headquarters office early in 1939 and later that year took charge of sales.

Lincoln Electric Official Dies

Edward W. P. Smith, consulting engineer for The Lincoln Electric Company, died September 15 while en route from Indianapolis to Cleveland. He had filled an engagement before the American Welding Society the previous night. He had been in the Lincoln organization 20 years and was an authority on welding practices. Recently he had traveled extensively in the interest of the war-production program.

He was a native of Cleveland and was educated at Colorado College, Colorado Springs. Before joining the Lincoln staff he worked for the city of Cleveland and Westinghouse Electric and Manufacturing Company. In addition to membership in the American Welding Society he was affiliated with the American Society of Mechanical Engineers, the American Society for Testing Materials and the Cleveland Engineering Society.

Fain to Chemical Warfare Service

Dr. J. Mitchell Fain, who has been with Foster D. Snell, Brooklyn, has joined the Chemical Warfare Service. Until called into the service he was engaged in chemical-engineering work connected with the processing of strategic materials.

WANTED
Refinery Design Engineer

Regular position for man with thorough knowledge of pressure vessel and piping design. Experience as chief draftsman and construction engineer is desirable. Location middle west. Medium size independent company. In reply please specify personal data, experience, draft status and salary required. Reply, Box 409, c/o Petroleum Refiner, Houston, Texas.

Following designing engineers available for company with war contracts as a group. Experienced in Chemical and Refinery design: Piping, Mechanical, Pressure Vessel, Structural, one each, and two designing draftsmen. Box 550, c/o The Petroleum Refiner, Houston, Texas.

CHEMIST OR CHEMICAL ENGINEER

B.S. or M.S. Degree; previous petroleum refining or laboratory experience preferred. Reply must list personal and other pertinent data including starting salary. Box 604, c/o The Refiner, Houston, Texas.